CALIFORNIA ENERGY COMMISSION

ISSUES AND ENVIRONMENTAL IMPACTS ASSOCIATED WITH ONCE-THROUGH COOLING AT CALIFORNIA'S COASTAL POWER PLANTS

APPENDICES

Support Studies and Technical Appendices

Staff Report

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CEC-700-2005-013-AP-A

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APPENDIX A: AN ASSESSMENT OF THE STUDIES USED TO DETECT IMPACTS TO MARINE ENVIRONMENTS BY CALIFORNIA'S COASTAL POWER PLANTS USING ONCE-THROUGH COOLING

Appendix A finalizes Dr. Michael Foster's Draft Consultant Report of February 2005 (CEC-700-2005-004-D). Appendix B Provides the Author's Response to Comments

ABSTRACT AND SUMMARY

There are 21 coastal and estuarine power plants in California that, combined, use nearly 17 billion gallons of seawater daily for once-through cooling (map on page 12). The purpose of this report was to review the adequacy of existing studies to accurately determine the effects of this use of seawater on the marine environment. The effects (impacts) generally occur from the discharge of heated water (thermal), the entrapment and death of large marine organisms on cooling system intake screens (impingement), and the death of small plants and animals that pass through the intake into the plant (entrainment). The review showed that because of problems with study designs and analyses, and lack of current information, the accuracy of the described impacts of over half of these plants (13) is unknown (summary table on page 14). Assessments of the effects of the cooling systems of six plants, Diablo Canyon, Huntington Beach, Morro Bay, Moss Landing, Potrero, and South Bay have been done since 1995 using currently accepted methods, and provide a reasonable understanding of impacts. A new study is about to be completed for Encina. Studies at the San Onofre Nuclear Generating Station were thorough and well done, but are now nearly 20 years old. New studies, especially of entrainment that incorporate estimates of proportional losses to larval populations, should be considered for this plant.

The assessments at the 13 power plants with unknown accuracy were done in the 1970's through the early 1980's, with occasional monitoring since that time. The thermal plumes from these plants are generally incompletely described, and sampling for thermal impacts (impacts of the thermal discharge on the environments where the water is discharged) incompletely done and commonly done with inappropriate sampling designs such that thorough detection of impacts is unlikely. Some entrainment studies (assessment of mortality of small organisms in the water caused by passing through the plant) for a particular plant were never done at that plant but, instead, were based on "surrogate" studies done at other, putatively similar plants. The rest of the entrainment studies were based on sampling methods (e.g., sampling at the intake or the discharge with a pump) that likely provide biased estimates of entrainment. In many cases assessment of entrainment impact was further compromised by assuming entrainment mortality was less than 100%. Few of these entrainment studies

incorporated sampling designs that allow the estimation of impact based on Proportional Mortality (PM), the proportion of larvae subject to entrainment (in the source water) that are entrained.. In almost all cases, the only impacts considered were those to commercial species. Impingement (larger organisms caught on intake screens) sampling was adequate at many of these plants, but the results may not be useful to evaluate current impacts because some plants were only studied in the late 1970's and early 1980's. Many natural populations, particularly fishes, have changed since then. Cumulative impacts have not been assessed at any of the power plants except Huntington Beach.[1] These may be particularly large in areas like Santa Monica Bay where multiple power plants use the same, local water body for cooling.

In addition to the original thermal studies, many current NPDES permits require monitoring, often yearly, that may include water quality profiles, infaunal sampling, etc. A review of some of this monitoring at power plants in the Los Angeles region indicated that the stations sampled are usually a subset of those used in the original thermal impact studies. Since the original studies were generally not well designed to detect impact, it is even more unlikely that such NPDES monitoring will detect impacts; the scientific basis for and usefulness of much of this monitoring to test hypotheses about thermal impacts are questionable. Similarly, a review of some of the NPDES monitoring at power plants in the San Francisco Bay region indicated monitoring is often focused on detecting metal or organic pollutants in the discharge. This seems to be done because power plant wastes are sometimes discharged with the cooling water. The discharged cooling water alone should contain little other than what is present when it is pumped into the power plant. If power plant wastes were diverted into waste treatment facilities there should be no need for monitoring pollutants in the discharge. Overall, while these studies may fulfill some regulatory requirement, they appear to be of little use in detecting impacts to Bay environments, and some studies would be unnecessary with changes in waste control and discharge.

There is no question that the once-through cooling systems of coastal power plants cause adverse environmental impacts - the cooling systems kill vast numbers of marine plants and animals, and may alter receiving water habitats over large areas. The severity of the impact can be ecologically important - conclusions by Regional Water Quality Control Boards of "no adverse impact," based on studies done in the 1970's and early 1980's and more recent NPDES monitoring, have been shown to be wrong at all plants recently reassessed using study approaches and analyses based on present scientific knowledge. For example, recent studies at Moss Landing and Morro Bay have shown that power plant cooling systems previously thought to have no adverse impacts may kill 10-30% of the larvae of particular fish species in the source water. It can be argued that while the early impact assessments were, in retrospect, of uncertain

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[1] Cumulative impact assessment is required under CEQA but not under Section 316(a) or (b) of the federal Clean Water Act.

accuracy, they were acceptable given knowledge at the time. This is true relative to the ability to identify larvae and models available to evaluate impacts, but it is not true for sampling designs. Pilot studies to determine the most accurate way to sample entrained larvae and to determine putative survivorship after passing through a cooling system were poorly designed, and insufficient attention was given to sampling designs that would optimize detection of thermal and entrainment impacts. Moreover, Regional Water Quality Control Boards evaluate NPDES permits for all of these power plants every five years. Plants have gone through at least 4 permit cycles since 1980, providing ample opportunity for review and to require properly designed studies as new information has become available. When such studies have been required, the requirement has commonly occurred because of evaluations from technical advisory groups that have included outside experts.

These recent findings and the review of prior studies indicate that the marine environment impacts of over half of California coastal power plants that use once-through cooling are largely unknown[2]. At the same time, many populations of marine organisms in California's coastal and estuarine environments have severely declined, and coastal habitats have been degraded. While once-through cooling systems are only one of many impacts to the coastal marine environment, their impacts can be large. Regulatory oversight of most of these power plants is, with few exceptions, inadequate, with potentially serious environmental consequences.

Introduction

In California, coastal and estuarine power plants with once-through cooling systems are permitted to draw nearly 17 billion gallons of water per day from the environment (natural waters) into the plants to remove waste heat produced during power generation, and then discharge the heated water back into the environment. The elevated temperature of the discharged water can impact natural environments via thermal effects, commonly called 316(a) impacts because they are regulated in part under Section 316(a) of the Federal Clean Water Act. Other impacts are caused when large organisms are caught and killed on intake screening structures (impingement), and when the small organisms in the water that pass through the screens and the cooling system are exposed to turbulence and elevated temperatures (entrainment). Impingement and entrainment are commonly called 316(b) impacts because they are regulated in part by Section 316(b) of the Federal Clean Water Act. They are often referred to as 316(a)-like and 316(b)-like for determination of impacts as part of a California Environmental Quality Act (CEQA) review. The purpose of this review was to evaluate how well these impacts have been assessed for the 21 coastal and

[2] This conclusion is in sharp contrast to that of most of the Regional Water Quality Control Boards that regulate these plants (Regional Water Board conclusions based on current NPDES permits for each plant are summarized in: Aspen Environmental Group, October 2002. Coastal Power Plant Inventory.

estuarine power plants in California, including those in the San Francisco Bay-Delta, that are currently operating using once-through sea water cooling systems.

The responsibility for the assessment of thermal, impingement, and entrainment impacts in California most commonly rests with the Regional Water Quality Control Boards (RWQCB). The Regional Board responsible for a particular power plant varies depending on plant location. The assessments, usually done by consultants hired by the power plant owner, occur in the form of impact assessment studies submitted as reports to a Regional Board, and used by the Board to evaluate impacts as part of the process of issuing a National Pollution Discharge Elimination System (NPDES) permit for the power plant discharge. Permits are usually renewed every 5 years. Similar studies and reports have been done for the California Energy Commission and the California Coastal Commission under the California Environmental Quality Act when power plants cooling systems have been modified. To evaluate how well impacts are assessed, these 316(a) and 316(b) reports were reviewed to determine how, and how well, the thermal plume was described, how sampling or other studies were done to detect impacts from the thermal plume, how and when impingement impacts were sampled, how entrainment impacts were determined (particularly the sampling design used to provide the data for estimates of larvae entrained), and when these studies were done. The latter is important because many nearshore fish populations have changed greatly over the past 30 years. Relevant reports were not available at some Regional Water Quality Control Boards. As a result, many reports had to be obtained from the libraries of environmental consulting companies and particular power plants. Reports for some power plants, particularly Receiving Water Monitoring Reports, were not reviewed (see individual power plant reviews) because not all power plants could be visited. Reports published after August 2003 were not systematically reviewed.

This is a review of the scientific basis of impact assessment, not particular regulations or the opinions of particular regulatory agencies or power plant operators. Knowing what the effects of power plant cooling systems are, as accurately as is reasonably possible, is fundamental to all regulatory assessment. Such knowledge is necessary to accomplish the purpose of the regulations.

Standards for Evaluation

While Sections 316(a) and (b) require studies to determine impacts they generally do not specify what metrics (e.g. abundance of species x) should be used or how the studies should be done. These are typically proposed by consultants hired by the power plant owner and approved by the Regional Water Quality Control Boards (or, relatively recently, by the California Energy Commission and California Coastal Commission relative to the California Environmental Quality Act if the power plant falls within their regulatory purview).

Study designs and metrics approved by the Regional Water Quality Control Boards were rarely reviewed by independent experts. This changed in the 1980's when the California Coastal Commission required thermal, entrainment and impingement studies associated with San Onofre Nuclear Generating Station to be designed and supervised by a committee composed of university scientists and representatives from environmental groups and the plant owner (see review of San Onofre Nuclear Generating Station). This committee used study designs and approaches to impact assessment that have been applied, with modification based on more recent analytical approaches and the operational and environmental setting of a particular plant, in subsequent impact assessments at other power plants. Most of these recent assessments have used a Technical Working Group that includes independent scientists plus representatives of relevant agencies, the plant owner/operator and, in some cases, environmental groups, to oversee study design, implementation, data and impact analyses, and impact interpretation.

The study designs for these recent assessments (see Literature Cited in the individual reviews of, for example, Diablo Canyon Nuclear Power Plant, and Huntington Beach, Moss Landing, and Morro Bay Power Plants) were used as the standard against which all studies were evaluated. The logic and science behind these recent designs are briefly discussed below. A thorough review is being done for the Energy Commission in a separate report (P. Raimondi, J. Steinbeck and G. Cailliet, in preparation).

Impact Analyses for an Operating Plant

Thermal Impacts

Thermal impacts occur as a result of discharging water used to cool the power plant back into the natural environment. Temperature is sampled in the receiving water under the full range of operating and environmental conditions and used to produce a 3-dimensional (horizontal and vertical) map of thermal plume distribution. This map shows the probability of a particular elevation in temperature above ambient (delta T; often in 2 degrees F increments from the highest down to 2 degrees F) occurring within the plume and on any substrate the plume contacts. The map is used to define areas of varying plume contact with the substrate.

In addition, benthic organisms are sampled along gradients of temperature caused by plume contact and analyzed for changes related to changes in temperature. Sampling designs for each benthic habitat type are analyzed for statistical power to detect change, and modified depending on the level of detection desired. Since gradient designs can be confounded by variables other than temperature (e.g. gradients in grain size), sampling designs and analyses strive to separate the effects of these other variables. Laboratory studies may be necessary to better determine if temperature is likely to be the most important cause of a change. Unless the natural receiving waters are confined such that plume dissipation is restricted (i.e. most often a bay or river), thermal effects on organisms in the water column (plankton and nekton) are assumed to be minimal and normally not sampled for possible impacts.

Entrapment and Impingement Impacts

Offshore intakes entrap fish when the fish swim into the long intake pipe and do not or cannot (because of intake velocity) escape. They may also entrap larger animals such as marine mammals, birds, and turtles. Once entrapped the fish tire and become impinged on the intake screens, or are killed during heat treatments done to removed organisms from the intake system. Shore intakes kill fish when currents created by the intake pumps pull the fish against the intake screen. Even short intake tunnels can increase shoreline intake impingement as fish tend to congregate around such structures. Impingement sampling methods are straightforward: organisms caught on the intake screens during normal operations and heat treatments are identified and counted. Studies are designed to produce an accurate estimate of all fishes and invertebrates impinged during a typical year, and repeated, especially if source populations change. Velocities of 0.5 feet per second or less across intake screens are currently recommended as Best Technology Available[3].

Entrainment Impacts

Entrainment studies estimate the kinds and number of organisms killed (primarily larvae) as a result of passing through the power plant cooling system. Literature review and preliminary sampling are used to define the species whose larvae are entrained and the waters from which they likely come. These species are usually fish, and invertebrates with large larvae such as crabs. Larvae of other invertebrates are impacted, but are difficult to sample due to their small size, and often difficult to identify to species (the latter may change as molecular techniques become less expensive). Adults and other stages of small planktonic invertebrates (e.g. copepods) and phytoplankton (e.g. diatoms) are generally not sampled due to their small individual size and the assumption that because of their large population sizes and rapid growth and reproduction, ecologically important impacts are unlikely.

The water in front of the intake and at appropriate locations away from the intake (determined based on where larvae likely come from) is sampled using obliquely towed plankton nets with a mesh size at or close to 300 microns. This may vary depending on the larval characteristics of the species. The depth and temporal scale of sampling will vary depending on temporal variability in larval behavior and abundance. The goal is to provide as accurate an estimate as possible of the species composition, number, and size of larvae available in the water that are

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[3] Federal Register, July 9, 2004, Vol. 69, No. 131. Environmental Protection Agency, 40 CFR Parts 9, 122, 123, 124, and 125.

potentially subject to entrainment (samples from water away from the intake), and the species composition, number and size of larvae actually entrained (samples from water in front of the intake).

Larval mortality from passage through the cooling system is assumed to be 100%. Various studies have shown, using techniques ranging from ATP analyses (indicating tissue is 'alive') to survivorship of individuals collected from the discharge (usually determined over a few days) that not all larvae are completely dead when they exit the discharge. However, there are no studies of the subsequent survivorship and fecundity of these individuals in nature versus the survivorship and fecundity of similar individuals that are not entrained. The mortality estimates from traditional studies are generally high. Given this uncertainty and the lack of evidence indicating otherwise, 100% mortality is assumed.

Impact analyses, using available information from the scientific literature about the fecundity, size and stage-specific natural survivorship of each species, determine how many adult equivalents (Adult Equivalent Loss or AEL) or the fecundity of how many adult females (Fecundity Hindcasting or FH) are lost because of entrainment mortality. AEL and FH estimates also include mortality from impingement. Larval mortality itself is assessed based on larval abundances sampled at the intake and in the source water. Larval data from around the intake are scaled to intake volume and, in combination with similar data from the waters away from the intake, used to determine larval Proportional Mortality (PM) with the Emperical Transport Model (ETM). PM is the proportion of larvae subject to entrainment (in the source water) that are entrained. To assess the spatial extent of this impact, knowledge of local water movement combined with information from the literature on the larval longevity of each species is used to calculate the size of the water body (source water) from which the larvae of each species entrained could have come. The result is the proportion of larvae in a given area (or volume) of source water that are eliminated by entrainment. The average of these losses for all species assessed can be used as a surrogate for species not sampled, and provide an overall estimate of plankton mortality from entrainment. The results can also be used to estimate the amount of equivalent habitat lost in, for example, a Habitat Production Foregone (HPF) analysis. Such analyses provide estimates of impacts to all populations, not just commercial or recreational species (see literature cited for Moss Landing and Morro Bay Power Plants).

Impact Analyses for New Power Plants or Those Being Modified

For these situations, modeling is used to estimate the distribution of the new thermal plume, and sampling for thermal effects is designed such that predicted areas of impact and no impact are sampled before and after the impact occurs - so called Before After Control Impact (BACI) or Before After Control Impact Paired (BACIP) sampling designs (see reviews and literature cited for San

Onofre Nuclear Generating Station and Diablo Canyon Nuclear Power Plant). These designs provide better evidence for thermal impacts due to plant operation than do gradient analyses. Additional sampling stations are included in the pre-impact period so that BACI designs can be used even if the plume predictions turn out to be inaccurate. Entrainment studies can be done if the intake location and operational cooling water flow rates are known. The thermal impacts of modifications to existing plants can be estimated by determining the effects of the existing plume and using plume modeling to predict effects after modification (see review and literature cited for Moss Landing Power Plant). The predicted new plume and its thermal impacts can be tested with plume measurements and additional sampling after the modified plant begins operation. The effects of modifications on impingement can be estimated based on data from the unmodified plant and the new intake velocities and flow rates, and these estimates tested after the modified plant becomes operational. Impingement cannot be modeled for a new plant, so can only be determined after operation begins. If rigorous and recent entrainment studies are available for an existing plant, entrainment after modification can be estimated using data from these studies and the modified flow rates.

In all cases, it is important to note that these approaches, particularly for entrainment impacts, are still subject to considerable uncertainty related to the ability to accurately sample the relevant organisms, uncertainties concerning their behavior, dispersal, growth and natural survivorship, and assumptions of the models used. However, they incorporate the best available science within the confines of reasonable cost, and thus provide the most accurate and cost effective approaches currently available.

Acknowledgments

L. McConnico (Moss Landing Marine Laboratories) assisted with report reviews, and P. Raimondi (UC Santa Cruz) assisted with the San Onofre Nuclear Generating Station review. H. Navrozali (SDRWQCB) assisted with locating reports and providing other information for plants in the San Diego area, and T. Dunbar (NCRWQCB) assisted with reports for Humboldt Bay Power Plant. J. Steinbeck (Tenera Environmental) provided information on recent 316(b) studies. Staff at the LARWQCB) and the SFBRWQCB could not locate relevant reports for any of the many plants in their Regions, and indicated they may not have copies. Most reports for these plants were located and reviewed at the power plants or other sources. C. Mitchell and S. Beck (MBC Applied Environmental Sciences) provided access to the numerous reports and other information on power plants in the Los Angeles region. G. Chammas (Mirant California, LLC) provided access to reports for Pittsburg and Contra Costa power plants, and M. Krone (PG&E) provided access to reports for Hunters Point Power Plant. In addition to formal comments (see Responses to Public Comment on "ASSESSMENT OF THE STUDIES USED TO DETECT IMPACTS TO MARINE ENVIRONMENTS BY CALIFORNIA'S COASTAL POWER PLANTS USING

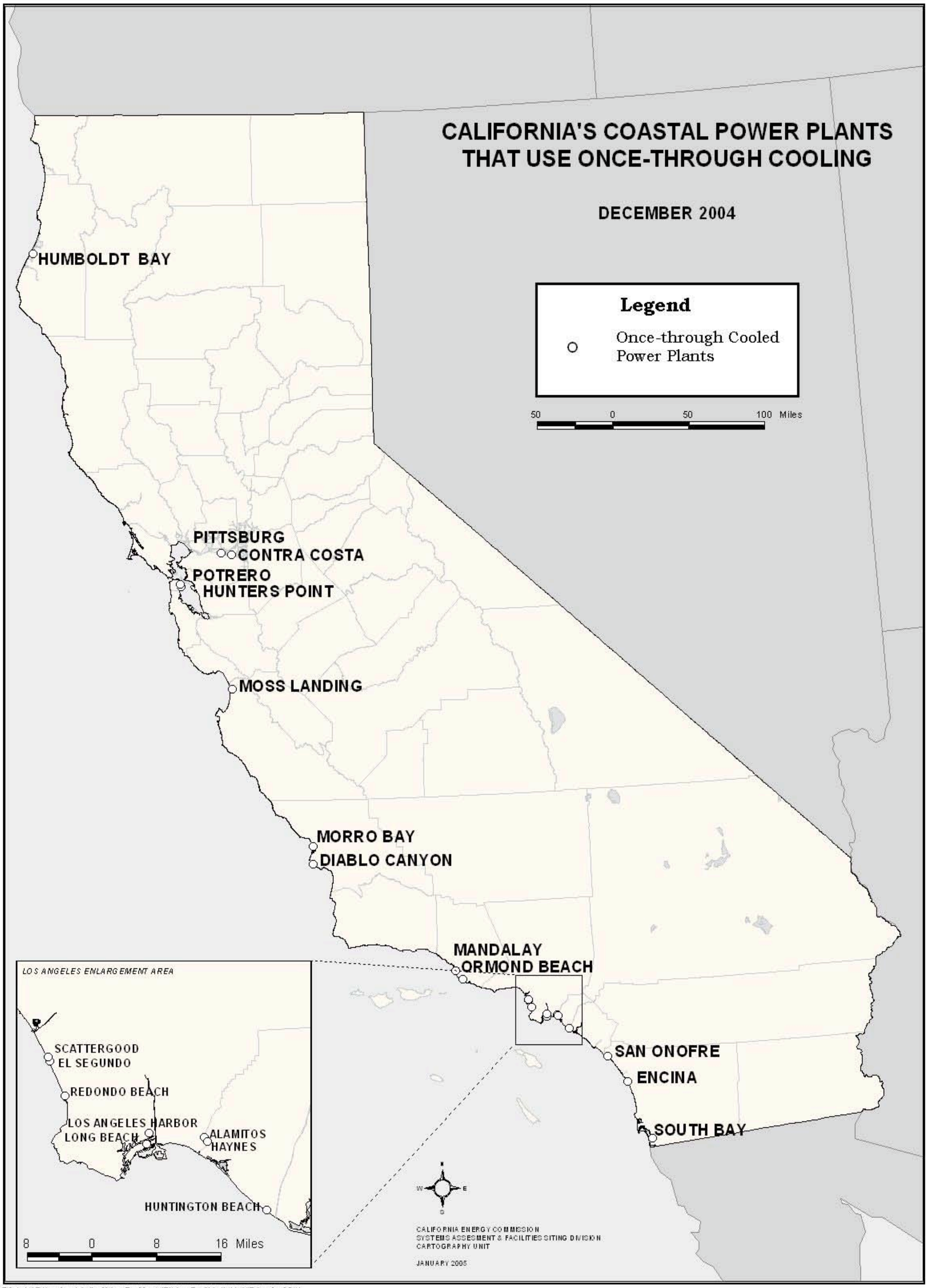
ONCE-THROUGH COOLING"), R. Anderson (CEC), S. Beck, G. Cailliet (Moss Landing Marine Laboratories), J. O'Hagan (CEC), P. Raimondi, J. Steinbeck, M. Thomas (CCRWQCB) and R. York (CEC) provided informal comments on preliminary drafts.

Commonly Used Abbreviations

AFC: Application for Certification
BTA: Best Technology Available
CCC: California Coastal Commission
CCRWQCB: Central Coast Regional Water Quality Control Board
CDFG: California Department of Fish and Game
CEC: California Energy Commission
CEQA: California Environmental Quality Act
CVRWQCB: Central Valley Regional Water Quality Control Board
LARWQCB: Los Angeles Regional Water Quality Control Board
MGD: Million Gallons per Day
NCRWQCB: North Coast Regional Water Quality Control Board
NMFS: National Marine Fisheries Service
NPDES: National Pollution Discharge Elimination System
SDRWQCB: San Diego Regional Water Quality Control Board
SFBRWQCB: San Francisco Bay Regional Water Quality Control Board
SWRCB: State Water Resources Control Board
RWQCB: Regional Water Quality Control Board

Units

Different units have been used in the studies reviewed, occasionally within the same report. In this report, all units are reported in the British/U.S. System.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SUMMARY TABLE

Power Plant	Permitted Volume (MGD)	Most Recent Entrainment Study	Assessment of Thermal Studies	Assessment of Impingement Studies	Assessment of Entrainment Studies
Alamitos	1275	1981	Incomplete	May be adequate - recent reports not reviewed	Accuracy** unknown - out of date
Contra Costa	341	1979	Possibly incomplete - studies need thorough review	Adequate in 1979 - now out of date	Accuracy unknown - mortality likely under estimated and study out of date
Diablo Canyon Nuclear*	2540	1998	Thorough and continuing	Adequate	Adequate
El Segundo	605	1980	Adequate	Probably adequate - recent impingement studies not reviewed	Accuracy unknown - study out of date
Encina	857	In progress	Likely incomplete - studies need thorough review	New study in progress	New study in progress
Haynes	1271	1979	Incomplete	Appears adequate - recent reports not reviewed	Accuracy unknown - study out of date
Humboldt Bay	78	1980	All studies need review - likely incomplete	Adequate in 1980 - now out of date	Inaccurate - mortality under estimated and study out of date
Hunters Point	412	1979	Possibly incomplete - studies need thorough review	Adequate in 1980 - now out of date	Inaccurate - mortality under estimated and study out of

					date
Huntington Beach*	507	2004	Adequate	Adequate	Adequate
Long Beach	261	1979	Likely incomplete - studies need thorough review	Appears adequate	Accuracy unknown - study out of date
Los Angeles Harbor	110	1981	May be adequate - studies need thorough review	Appears adequate	Accuracy unknown - study out of date
Mandalay	255	1982	Accuracy unknown	May be adequate - recent reports not reviewed	Accuracy unknown - study out of date
Morro Bay*	668	2001	Adequate	Adequate	Adequate
Moss Landing*	1224	2000	Thorough and ongoing	Adequate	Adequate
Ormond Beach	688	1980	Incomplete	May be adequate - recent reports not reviewed	Accuracy unknown - study out of date
Pittsburg	1070	1979	Incomplete - studies need thorough review	Adequate in 1979 - now out of date	Accuracy unknown - study out of date
Potrero*	226	2002	Incomplete	Incomplete	Likely adequate - 2002 study yet to be reviewed
Redondo Beach	881	1980	Incomplete	Appears adequate - recent reports not reviewed	Accuracy unknown - study out of date
San Onofre Nuclear*	2580	1987	Thorough and continuing	Adequate	Adequate but may be out of date
Scattergood	495	1981	Not reviewed	Possibly incomplete	Accuracy unknown - study out of date

South Bay	601	2004	Appears adequate - needs independent review	Adequate	Appears adequate - needs independent review

*A technical working group including independent scientists was established to guide assessment and analyses.

** The accuracy of information is defined herein as how well entrainment impacts are estimated, including that the information pertains to the present state of marine populations. For details see Standards for Evaluation in the Introduction.

ALAMITOS GENERATING STATION

Background

The Alamitos Generating Station in Long Beach is located on the west side of the San Gabriel River, across the river from the Haynes Generating Station and approximately 1.8 miles from where the river flows into San Pedro Bay. The Station draws cooling water from a channel connected to Alamitos Bay, and discharges it into the San Gabriel River (See AEG, 2002, for site details). The river at the point of discharge is tidally influenced and saline for most of the year.

316(a) – Thermal Impacts

Description of thermal plume

Current thermal plume distribution is based on EQA/MBC (1973), the 316(a) study done in 1971-72. This study was done using temperature surveys (including profiles) at different times of the year. Since Alamitos and Haynes Generating Stations both discharge into the San Gabriel River at about the same point the temperature effects of the discharges cannot be distinguished. EQA/MBC (1973) examined the combined effects of these two discharges.

EQA/MBC (1973) shows that these generating stations heat the entire river between them and San Pedro Bay to temperatures well over 10 degrees F above ambient (delta T at the discharge for both plants is around 20 degrees F). At most times the water being heated is salt water, flowing up the river with the tide. This heated water then flows back into San Pedro Bay, heating between 440 and 1650 acres of surface water to a delta T of 4 degrees F or higher. In addition, the 4 degrees F or higher delta T water contacts the shoreline for around 8000 feet north and 8000 feet south of the river mouth (scaled from EQA/MBC 1973; Fig. 4-22). The study suggests that elevated temperature water contacts the ocean bottom no deeper than 5-10 feet but the location of the sampling stations indicates this is not well defined. The probability of surface delta T's were calculated, but not for the benthos.

In addition to EQA/MBC (1973), MBC (1996) sampled temperature, dissolved oxygen, and pH at 12 stations, three in the San Gabriel River and the rest offshore the river mouth in San Pedro Bay, in March and September, 1996 at flood and ebb tide. The NPDES permits for Alamitos and Haynes Generating Stations specify water quality profiles at these 12 stations, and the profiles have been done yearly since 1978 (S. Beck, MBC Applied Environmental Sciences, pers. com.). Findings have been similar, and it was concluded that water temperatures were elevated at sites in the San Gabriel River, and elevated water temperatures extended into San Pedro Bay at stations closest to the river mouth.

Effects of thermal plume

Benthic sampling of the infauna in the portion of the river affected by the discharges revealed “a fauna impaired by generally poor environmental conditions,” but concluded it is difficult to determine the primary cause of environmental degradation because there are many discharges into the river, not just heated water from the power plant (EQA/MBC 1973). Based on sampling along the rock jetties at the river mouth it was concluded that intertidal communities were “impoverished,” probably as a result of the river, but did not suggest what in the river was affecting these communities. Benthic infauna in San Pedro Bay near the river mouth was “highly variable,” but EQA/MBC (1973) concluded the infauna was not adversely affected by the discharge from the river. However, all the sampling stations were within the influence of at least the surface thermal plume [compare Fig. 3-10 (sampling stations) with Fig. 4-20 (plume distribution) in EQA/MBC 1973]. Fish caught in trawls near the river mouth had a high incidence of caudal fin disease. No trawls were done in the river.

Conclusions

Additional studies are needed to better define the impact of the thermal discharge on the benthos of San Pedro Bay. Moreover, the effects of the heated water on sandy beaches were not determined, and studies of the rock jetties were minimal. The impacts to the river may be extreme.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

See 316(b) discussion for Haynes Generating Station also. In the 316(b) study for Alamitos, SCE (1982) used the Haynes Generating Station data (IRC 1981) and simply scaled it to Alamitos Generating Station flow rates. For the reasons given in the discussion of Haynes, the entrainment sampling methods make the accuracy of any entrainment mortality estimates questionable. The impingement study (SCE 1982) appears adequate. However, intake velocities can be up to 2 feet per second, well above the 0.5 feet per second or less currently accepted as BTA for shoreline intakes.

Conclusions

A new 316(b) study needs to be done for this generating station if current entrainment impacts are to be accurately known. A BTA analysis needs to be done for at least the intake structure. Because Alamitos and Haynes Generating

Stations draw water from the same Bay, a single new 316(b) study, if properly done, could suffice for both.

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CONTRA COSTA POWER PLANT

Background

The Contra Costa Power Plant is located near Antioch on the southern shore of the San Joaquin River (San Francisco Delta) approximately 6 miles east of the Pittsburg Power Plant. According to AEG (2002), only Units 6 and 7 are currently operational. The intake for these units is on the shoreline, and discharge is into an approximately 500-foot long discharge channel that empties into the river.

316(a) – Thermal Impacts

Description of thermal plume

Thermal studies for this plant were done in a similar way and at the same time as for the Pittsburg Power Plant (PG&E 1992, 1993, 1998). A first study in 1972, likely similar to that for the Pittsburg Power Plant, may have been done but the report could not be located. Units 6 and 7 discharge into the channel at a delta T of up to 21 degrees F (varied depending on striped bass season), and the channel discharges into the river at a maximum delta T of 18 degrees F. PG&E (1993) indicates that the thermal plume for Units 6 and 7 is very localized, can contact approximately 500 feet of shoreline and the surface of the river out to approximately 500 feet. The delta T 2 degrees F isotherm covers 5 - 45 acres of San Joaquin River surface and varies greatly with tide and river flow. PG&E (1993) does not completely report the methods used for this determination.

Effects of thermal plume

PG&E (1993) reports on sampling of nekton and plankton similar to that done for the Pittsburg Power Plant (see Pittsburg Power Plant review). For the Contra Costa Power Plant, this sampling was done primarily to evaluate the effects of the plume on organisms in the water, particularly striped bass. The smallest mesh size used for sampling was 500 microns. There is no recent information concerning plume influence on the subtidal benthos. Benthic studies may have been done in 1972. If this is the case, then sampling design is similar to those for the Pittsburg Power Plant and result in an inadequate impact analysis (see Pittsburg Power Plant review).

Conclusions

New studies would provide information on the current plume which is likely reduced from that in 1991-92 due to changes in plant operation. Existing and possible new studies should be used to develop a 3-dimensional model of the plume under the full range of operating and river conditions. This model could be then used to help evaluate the adequacy of existing studies of biological impacts and to design new studies as appropriate. Such studies may be done if the CVRWQCB approves new BTA measures that result in significant changes to the plant and the discharge (G. Chammas, Mirant, pers. comm.).

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

The primary 316(b) study for this power plant was done from April 1978 to April 1979 (PG&E 1981). Methods were similar those done at the same time at the Pittsburg Power Plant, and subject to the same problems associated with pump sampling at the discharge to estimate organisms entrained (see details in Pittsburg Power Plant review). The inadequacies of these designs are apparent from the reports themselves. For example, the "mass balance" study done at Contra Costa (PG&E 1981) to examine if discharge samples were representative of intake samples found the overall mean density of larval and juvenile fish was *higher* at the discharge than at the intake – as if the power plant were producing fish. The report dismisses this as simply the result of the vertical stratification of organisms at the intake versus that they are "well mixed" (an untested assumption) in the discharge, combined with discrete depth sampling at both places. That is, the intake samples were probably taken from a location in the water column with lots of organisms, while any discharge sample is "well mixed," and therefore an average. These sorts of differences simply illustrate the unknown accuracy of discharge (or intake) sampling with pumps, and thus the fundamental flaw with this approach to entrainment sampling. Like Pittsburg, entrainment loss calculations assumed 100% mortality for all organisms except striped bass and the shrimp, *Neomysis*. Losses of these were adjusted based on discharge temperature. The relationship between through-plant mortality and temperature was apparently based on laboratory and field studies, but the details of the studies necessary to evaluate their validity are not provided in PG&E (1981).

Special studies on entrainment impacts on striped bass have continued (see PG&E 1993, 1998), and are similar to those for Pittsburg Power Plant (see Pittsburg Power Plant review). Impingement studies appear adequate, but are now out-of-date.

Conclusions

The original 316(b) study (PG&E 1981) is flawed due to sampling methods, including discharge sampling with a pump. It is now also out-of-date. A new, well designed 316 (b) study needs to be done for this plant, along with a determination of BTA for the cooling system.

Later studies have focused primarily on striped bass. These studies need thorough, rigorous review by entrainment and fisheries experts to determine how well they estimate the effects of entrainment and impingement on striped bass populations in the source water.

Literature Cited

AEG (Aspen Environmental Group). 2002. Contra Costa Inventory and 316(a) and (b) Summary. In: Coastal Power Plant Inventory - Plant Facility and Operational Data. CD ROM prepared for the California Energy Commission CD ROM prepared for the California Energy Commission.

PG&E (Pacific Gas and Electric Co.). 1981. Contra Costa Power Plant cooling water intake structures 316(b) demonstration (prepared by Ecological Analysts). Pacific Gas and Electric Co., San Francisco (not consecutively paginated).

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PG&E (Pacific Gas and Electric Co.). 1993. Best technology available - 1993 technical report for the Contra Costa and Pittsburg Power Plants. Pacific Gas and Electric Co., San Francisco (not consecutively paginated).

PG&E (Pacific Gas and Electric Co.). 1998. Draft - Revision 3: multispecies habitat conservation plan - Pittsburg and Contra Costa Power Plants. Pacific Gas and Electric Co., San Francisco (not consecutively paginated).

DIABLO CANYON NUCLEAR POWER PLANT

Background

The Diablo Canyon Nuclear Power Plant began full operation in 1986. The facility takes water from a shoreline intake cove constructed for the power plant, and discharges it into the rocky intertidal zone of Diablo Cove (Tenera 2000a, AEG 2002).

316(a) – Thermal Impacts

The description of the thermal plume and monitoring of its effects began prior to construction in 1976 and continues. In 1995, associated with a request by the plant owner to reduce thermal effects monitoring, the CCRWQCB established a Technical Working Group to evaluate and summarize the thermal plume distribution and thermal impact information based primarily on monitoring data from 1976-1995. This resulted in perhaps the most thorough and rigorous analyses of the effects of a thermal discharge (Tenera 1997). Thermal effects monitoring with periodic summaries continues (e.g. Tenera 2002).

316(b) – Impingement, Entrainment and Entrapment Impacts

A 316(b) study was done in 1985-1986 when the plant became fully operational. Questions arose over its accuracy. The CCRWQCB required a new 316(b) study (Tenera 2000; additional analyses in Raimondi 2003)) that was done in 1996-1998, a two year period (rather than the usual one) because there was a large El Niño oceanographic event during the first year.

This 316(b) study was done with oversight from an Entrainment Technical Working Group established by the CCRWQCB, and used many of the sampling designs and approaches developed for a similar study at the San Onofre Nuclear Generating Station in the late 1980's (see San Onofre Nuclear Generating Station review), as well as sampling to estimate larval Proportional Mortality using the ETM.

As a result of these recent studies, the environmental effects of the Diablo Canyon Nuclear Power Plant cooling system are now reasonably well known (reported in Tenera 1997; Tenera 2000; Raimondi 2003).

Literature Cited

AEG (Aspen Environmental Group). 2002. Diablo Canyon Inventory and 316(a) and (b) Summary. In: Coastal Power Plant Inventory - Plant Facility and Operational Data. CD ROM prepared for the California Energy Commission CD ROM prepared for the California Energy Commission.

Raimondi, P. 2003. Cooling Water System Findings Regarding Clean Water Act Section 316(b) - Diablo Canyon Power Plant - NPDES Permit Order RB#-2003-0009. Central Coast Regional Water Quality Control Board, San Luis Obispo. 7 pp.

Tenera (Tenera Environmental Sciences). 1997. Diablo Canyon Power Plant Thermal Effects Monitoring Program and Analysis Report. Chapter 1 - Changes in the marine environment resulting from the Diablo Canyon Power Plant Discharge (prepared for Pacific Gas and Electric Co.). Tenera Environmental Services, San Francisco (not consecutively paginated).

Tenera (Tenera Environmental Sciences). 2000. Diablo Canyon Power Plant 316(b) Demonstration Report. (prepared for Pacific Gas and Electric Co.). Tenera Environmental Services, San Francisco (not consecutively paginated).

Tenera (Tenera Environmental Sciences). 2002. Diablo Canyon Power Plant Receiving Water Monitoring Program: 1995-2002 Analysis Report (prepared for Pacific Gas and Electric Co.). Tenera Environmental, San Francisco (not consecutively paginated).

EL SEGUNDO GENERATING STATION

Background

This power plant, located on Santa Monica Bay just south of the Scattergood Generating Station and north of the Redondo Beach Generating Station, draws cooling water from an intake located approximately 2500 feet offshore, and discharges heated water through a pipe approximately 2000 feet offshore (AEG 2002). The owner would like to add new generating units, and filed an AFC with the Energy Commission in 2000, and supplemental materials and responses to Data Requests in 2001. This information, and the adequacy of existing information about 316(a) and (b) impacts, are extensively discussed in Davis et al. (2002) and summarized below.

316(a) – Thermal Impacts

Existing studies (cited in Davis et al. 2002) are adequate to determine the distribution and biological impacts of the thermal plume.

316(b) – Impingement, Entrainment and Entrapment Impacts

Impingement studies at this plant are ongoing. An entrainment study has never been done at this plant. Instead, a study done at the Ormond Beach Generating Station (see Ormond Beach review) was used as a surrogate, and the results scaled to El Segundo flow rates. An entrainment study was done at the nearby Scattergood Generating Station but, among other study design problems, entrainment sampling at Scattergood likely produced very inaccurate estimates of larval fish abundances. The owner attempted to use recent plankton data from King Harbor (at Redondo Beach) but could not adequately demonstrate how similar the King Harbor plankton assemblage was to the plankton assemblage being entrained at El Segundo. The volume of cooling water proposed for the modified plant will likely increase impingement relative to recent levels. An analysis of BTA for the cooling system is needed. For these reasons, Davis et al. (2002) concluded that a new 316(b) study needed to be done to adequately assess current entrainment and evaluate BTA. A cumulative analysis of entrainment and impingement impacts is also needed, since two nearby power plants also use Santa Monica Bay water for cooling.

Literature Cited

AEG (Aspen Environmental Group). 2002. El Segundo Inventory and 316(a) and (b) Summary. In: Coastal Plants. CD ROM prepared for the California Energy Commission.

Davis, N., Foster, M., Koslowsky, S., Raimondi, P., Cailliet, G. and York, R. 2002. Biological resources, p. 4.2-1 to 4.2-47. In: Final Staff Assessment - El Segundo Power Redevelopment Project. California Energy Commission, Sacramento.

ENCINA POWER PLANT

Background

The Encina Power Plant intake is located in Aqua Hedionda Lagoon and the discharge is conveyed through a discharge channel across the beach and into the surf zone outside the lagoon (sees AEG 2002 for site details).

Various documents related to 316(a) and (b) impact assessment have been used as the basis of SDRWQCB NPDES permits for this plant since it began operating in 1954 (AEG 2002; Encina 316(a) & (b) Summary). The most recent documents used for the present permit are EA Engineering, Science and Technology (1997a, b). These were reviewed to evaluate the adequacy of marine impact assessment. It should be noted, however, that these most recent "studies" are based on very little new information and largely re-analyze and reinterpret data from prior studies. A new 316(b) study incorporating the modern sampling and analytical approaches discussed in the Introduction is scheduled to be completed for this power plant in June, 2005 (J. Steinbeck, pers. comm.). The need for a new 316(a) study is currently being evaluated by the SDRWQCB (H. Navrazoli, pers. comm.).

316(a) – Thermal Impacts

Description of thermal plume

The surface plume has been monitored and mapped using thermographs and aerial infrared photography since 1997, and plots of the probability of particular delta T's at a particular surface location are available. Based on these plots, the area within which there is a 5% probability of a delta T of at least 4 degrees F is approximately 1.2 miles long (up and down the coast from the discharge) and extending 0.6 miles offshore. Since the plume extends across the lagoon entrance to the north, some heated water enters the lagoon with incoming tides. The surface plume contacts approximately 1.2 miles of sandy beach, the rocky intertidal at the entrance to the lagoon and along the discharge canal, and a giant kelp (*Macrocystis pyrifera*) forest to the southwest (Southern Kelp Stand). No information was found on the distribution of the plume with depth.

Effects of the thermal plume

Various surveys have been done of the sandy beach and giant kelp canopies. According to the documents reviewed, these have concluded there are no biologically significant adverse effects of increased temperature, however "biologically significant adverse effects" are not defined. A careful critique of all the documents used in reaching this conclusion was not possible. Thorough, critical analyses of the data from the many different reports cited would be required to determine if this conclusion is justified. Apparently thermal effects on the rocky intertidal zone and in the lagoon have never been studied.

Conclusions

To properly determine 316(a) impacts, a 3-dimensional model of plume distribution must be constructed. This will require new studies of delta T with depth. The model then needs to be matched to benthic habitats so that areas of likely impact can be identified for further study (with designs and interpretation similar to those for recent thermal impact studies at Morro Bay Power Plant; DUKE 2001). The existing biological data for the sandy beach and kelp forest needs to be critically reviewed and analyzed to determine how well the sampling designs detect impact. This review and analysis will likely reveal that new studies are necessary for rigorous impact analyses. The effects of the plume on the rocky intertidal and lagoon need to be examined with new studies. The discharge system needs to be evaluated relative to Best Technology Available.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

No new 316(b) data on either entrainment or impingement data were obtained by EA Engineering, Science and Technology for their 1997(b) report; the report simply revisits and reinterprets existing data from the original 316(b) study done in 1979-1980 (SDGE 1980). The 1979-1980 entrainment study used different sized plankton net mesh at different times of the year (505 and 335 microns), only sampled source water in the lagoon, only examined 17 “target” species, did not measure the size of the larvae sampled, only calculated densities at the family-level, and only estimated Equivalent Adult Loss (based entirely on life-history information in the literature) for the three most abundant species entrained. Impingement data used for the 1997 report were also from 1979-1980. Fish species composition and abundance in the region have changed considerably since 1979-1980 (see review in Davis et al., 2002) such that using these old data is inappropriate for an assessment of current impingement impacts.

Conclusions

The conclusion by EA Engineering, Science and Technology (1997b) that entrainment and impingement losses are “insignificant” has little scientific basis. New entrainment and impingement studies are currently being completed.

Literature Cited

AEG (Aspen Environmental Group). 2002. Encina Inventory and 316(a) and (b) Summary. In: Coastal Power Plant Inventory - Plant Facility and Operational Data. CD ROM prepared for the California Energy Commission.

Davis, N., Foster, M., Koslowsky, S., Raimondi, P., Cailliet, G. and York, R. September 2002. Biological Resources. Section 4.2 in: Final Staff Assessment - El Segundo Power Redevelopment Project - Application for Certification (00-AFC-14), Los Angeles California. California Energy Commission, Sacramento.

DUKE (Duke Energy Morro Bay, LLC). 2001. Morro Bay Power Plant modernization project thermal discharge assessment report. Duke Energy Morro Bay, LLC, Oakland, CA (not consecutively paginated).

EA Engineering, Science and Technology. 1997a. Final - Encina Power Plant supplemental 316(a) assessment report. Vol.1 Text (note consecutively paginated - 6 chapters) and Vol. 2 Appendices (not consecutively paginated). Prepared for: San Diego Gas and Electric, San Diego.

EA Engineering, Science and Technology. 1997b. Final - Encina Power Plant Supplemental 316 (b) Assessment Report. Prepared for San Diego Gas and Electric, 101 Ash St., San Diego, CA 92112-4150 (not consecutively paginated - 5 chapters + appendices).

SDGE (San Diego Gas and Electric). 1980. Encina Power Plant: cooling water intake system demonstration. Vol. 1 & 2, and summary. Prepared for California Regional Water Quality Control Board (this report was not reviewed - all information from it based on information in EA Engineering, Science and Technology, 1997b).

HAYNES GENERATING STATION

Background

The Haynes Generating Station in Long Beach is located on the east side of the San Gabriel River, across the river from the Alamitos Generating Station and approximately 1.8 miles from where the river flows into San Pedro Bay. The generating station draws cooling water from Alamitos Bay. The water flows from Alamitos Bay through pipes under the San Gabriel River and then through a channel to the generating station. Heated water is discharged into the San Gabriel River (See AEG 2002, for site details). The river at the point of discharge is a tidally influenced and saline for most of the year.

316(a) – Thermal Impacts

Existing information

Current thermal plume distribution and its effects are based on EQA/MBC (1973); the 316(a) study was done in 1971-72. The study was done using temperature surveys (including profiles) and biological surveys at different times of the year. Since Alamitos and Haynes Generating Stations both discharge into the San Gabriel River at about the same point such that the temperature effects of the discharges cannot be distinguished, EQA/MBC (1973) examined the combined effects of these two discharges. The description of the study can be found in the Alamitos Generating Station review. Certain stations have been profiled for water quality since 1978 (see Alamitos review). The conclusion is repeated below.

Conclusions

Additional studies are needed to better define the impact of the thermal discharge on the benthos of San Pedro Bay. Moreover, the effects of the heated water on sandy beaches were not determined, and studies of the rock jetties were minimal. The impacts to the river may be very significant (see review of Alamitos Generating Station).

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

The intakes for this generating station are located in NE Alamitos Bay within the Long Beach Marina. The entrainment study was done October 1978 - November 1979 (IRC 1981). Maximum intake velocity recorded was 30 cm/sec (~1 foot per second). Entrainment was sampled bi-weekly during the day and night by pumping water from mid-depth (bottom is 10 feet below MLLW) “at the entrance of the intake conduit structure,” and during the night using Manta nets at the surface, Bongo nets for mid-water, and epibenthic Bongo nets for “near-bottom.” While sampling was done day and night, the time and duration of sampling within a 24-hour sampling period could not be determined from IRC (1981). Moreover, it is not clear how well pump sampling actually samples larvae being entrained. The mesh size of the sample nets was changed (from 335 to 202 microns) mid-way through the survey. It is not clear, however, if this was done for all the various nets used (the report mentions changing the nets used for the pump samples and “surface” plankton samples, but not the mid-water or epibenthic plankton nets). In addition to these potential problems, it is not clear how comparable pump and net sampling are. Impact was calculated as AEL only for “critical taxa,” (often also referred to as “target taxa”) many of which were identified only to large taxonomic groups (e.g. “Gobiid species complex”). The impingement study appears satisfactory.

Conclusions

It is not clear how accurately entrainment was sampled by the methods used - it is likely that the methods using pumps and various sorts of nets, the timing of sampling, etc. were not comparable and resulting estimates, therefore, may be inaccurate. Without knowing the accuracy of the methods, the accuracy of any resulting impact calculation based on these methods is questionable. Moreover, larvae were not well or comprehensively (only “target taxa”) identified, and only AEL was used to calculate impacts. Finally, the study was done nearly 25 years ago and there have probably been considerable natural changes in the local fish fauna since that time. A new 316(b) study using modern sampling and analytical approaches needs to be done at this plant to provide an accurate estimate of current entrainment impacts. The cooling system needs to be re-evaluated for BTA. Given the similar locations of the Haynes and Alamitos Generating Station intakes, a single 316(b) study could be designed to serve for both plants.

Literature Cited

AEG (Aspen Environmental Group). 2002. Haynes Inventory and 316(a) and (b) Summary. In: Coastal Power Plant Inventory - Plant Facility and Operational Data. CD ROM prepared for the California Energy Commission.

EQA/MBC. 1973 (Environmental Quality Analysts, Inc. and Marine Biological Consultants, Inc.) 1973. Thermal effect study: final summary report - Alamitos Generating Station and Haynes Generating Station. Prepared for Southern California Edison Company and Los Angeles Department of Water and Power, Rosemead and Los Angeles. 121 pp. + appendices.

IRC (Intersea Research Corporation). 1981. Haynes Generating Station Cooling Water Intake Study. 316(b) Demonstration Program. Prepared for the Los Angeles Department of Water and Power, Los Angeles, CA.

MBC (MBC Applied Environmental Sciences). 1996. National Pollutant Discharge Elimination System 1996 receiving water monitoring report, Los Angeles Region. MBC Applied Environmental Sciences, Costa Mesa. (not consecutively paginated).

HUMBOLDT BAY POWER PLANT

Background

The Humboldt Bay Power Plant cooling water intake and discharge are located in Humboldt Bay almost directly east of the entrance to the Bay. Intake occurs via a 1200-foot canal from the Bay, and discharge occurs through a 360-foot canal and then via 4 pipes under a rocky sea wall into the Bay (PGE, 1983a). The original plant had two fossil fuel units and one nuclear generating unit, but the nuclear unit has not been operated since 1976 (see AEG, 2002 for operational details).

316(a) – Thermal Impacts

Description of thermal plume

Thermal plume distribution is based on a study by PG&E (1983b) in 1982. The study consisted primarily of measuring temperature along the shore with slightly submerged probes to distances of 1000 feet north and south of the discharge. These data were compared to similar data from 1972. Highest temperatures (delta T = 25 degrees F) were recorded at the point of discharge, with delta T's of 4 degrees F extending between 50 to 150 feet north and south of the discharge. No measurements were made with depth or offshore, and the overall plume was not specified. PGE (1983a) states that in 1973 the surface plume covered 50 hectares of the Bay surface, but no data are given and the 1973 study was not available at the NCRWQCB where reports were reviewed. The plume, whatever its size and distribution in 1973, would be different now that the nuclear unit is no longer operating.

Effects of thermal plume

There were no studies of the biological effects of the thermal plume available at the NCRWQCB. Apparently a study was done in 1973; however the report is available at PG&E headquarters in San Francisco (M. Krone, PG&E, pers. com.) but was not obtained.

Conclusions

A new, thorough 316(a) study needs to be done for this plant to determine the environmental impacts of the discharge. The new study should be such that the 3-dimensional extent of the plume with isobaths of delta T of 2 degrees F and higher are determined under the full range of operating and tidal conditions. This plume map, combined with local bathymetric data, should be used in conjunction with prior data (see paragraph above) to determine if new studies of benthic impacts are needed.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

A 316(b) study was done at this plant in 1979-1980. Impingement sampling was done weekly or bi-weekly using standard procedures that appear adequate. Velocities at the intake screen were 1.3 feet per second, which exceed the current standard of 0.5 feet per second or less.

The samples used to estimate larval loss due to entrainment were taken by pumping known volumes of water from the discharge well located at the beginning of the discharge canal. The report states that comparisons with samples from the intake showed larval abundances were consistently lower at the discharge. It is not clear that the sampling methods used at the two locations were the same. Nevertheless, even though differences were found, discharge samples were still used as the basis of entrainment mortality estimates. Mortality of larvae in these discharge samples was assumed to be 29%, not the current standard of 100%, and adjusted accordingly in calculations of AEL. Many larvae were identified only into larger taxonomic groups, not to species. Sampling entrainment at the discharge is no longer considered acceptable due to larval loss and damage. Pumping samples is no longer considered acceptable because the larvae in such samples are not likely to be representative of those entering the intake (as sampled throughout the water column with a plankton net near the intake).

Conclusions

The design of the 316(b) study used as the basis for assessing the entrainment impact of the Humboldt Bay Power Plant cooling system is fundamentally flawed and out of date. If entrainment impacts are to be accurately assessed, new studies are required, including a BTA analysis for the intake and discharge. Since the intake is in a bay with a mix of offshore and estuarine species, a design similar to that used for the Morro Bay Power Plant (Tenera, 2001) should be considered for the 316(b) study. Impingement need to be updated.

Literature Cited

AEG (Aspen Environmental Group). 2002. Humboldt Bay Inventory and 316(a) and (b) Summary. In: Coastal Power Plant Inventory - Plant Facility and Operational Data. CD ROM prepared for the California Energy Commission.

PG&E (Pacific Gas and Electric Company). 1983a. Humboldt Bay Power Plant cooling water intake structures 316(b) demonstration. Pacific Gas and Electric

Co., San Francisco (2 vols., not consecutively paginated; report prepared by Ecological Analysts, Inc.).

PG&E (Pacific Gas and Electric Company). 1983b. Humboldt Bay Power Plant thermal effects comparison. Pacific Gas and Electric Co., San Francisco. 26 pp. + appendix.

Tenera (Tenera Environmental Services). 2001. Morro Bay Power Plant Modernization Project - 316(b) resource assessment. Prepared for Duke Energy Morro Bay, LLC, Oakland, CA. (not consecutively paginated).

HUNTERS POINT POWER PLANT

Background

The Hunters Point Power Plant, located on South San Francisco Bay south of the Potrero Power Plant, began operation in 1929. The plant withdraws Bay water from an intake basin that fills with water via a conduit that connects to the shore of the Bay. Discharge is via two shoreline structures in India Basin, a small arm of South San Francisco Bay (AEG 2002; PG&E 1982). The shoreline around the plant was extensively filled and otherwise modified between 1926 and 1979 (PG&E 1982, Fig. 2-15). The plant has not run since February, 2003, and discussions with plant personnel suggest it may be taken out of service in 2005.

316(a) – Thermal Impacts

Description of thermal plume

The discharge delta Ts range from 11-23 degrees F (PG&E 1973). The thermal plume was assessed by PG&E (1973) using surface remote sensing in 1971-1972. The 4 degrees F delta T isotherm extended approximately 2600 feet into India Basin during a day-long study in July, covering approximately 50 acres of surface water. Vertical temperature profiles suggested benthic contact occurred in the vicinity of the discharge. PG&E (1991) suggests that there may be extensive areas of plume contact with the bottom in the channel off India Basin where the discharge occurs, especially during low tide.

Effects of thermal plume

PG&E (1973) took benthic grab samples quarterly at ten different stations, and completed fish sampling (trawls and gill nets) at 5 sites. Benthic samples were taken in a line from the discharge to the south east to a distance of 3000 feet from the discharge. One station was to the north, but near Potrero Power Plant. The biological data were analyzed for impact by using multiple regressions to examine the relationship between organisms in the sample and surface temperatures taken at the time of sampling. Since the thermal plume changes with time, this sort of analysis does not necessarily test for the long term thermal effects which are of interest in an impact analysis. Only one of the fish sampling sites was outside the area of the thermal plume, but this site was very close to Potrero Power Plant. Quantitative analyses of the fish samples were done on biomass only. The mesh size of the gill net was changed during the study. Plankton samples were also taken at the intake and discharge.

An additional thermal effects study was done in 1989-1990 (PG&E 1991), with a particular focus on potential effects of the discharge on spawning and reproductive success of Pacific herring. No additional benthic sampling was done, but subtidal transects in the vicinity of the discharge were examined visually.

Conclusions

A more thorough evaluation of the thermal plume is needed to accurately describe its 3-dimensional structure under the full range of plant operational and tidal conditions. This might be done using existing data in PG&E (1973, 1991). This plume model then needs to be used to evaluate the adequacy of existing biological sampling to detect the magnitude and extent of impacts in all habitats contacted by the plume. The evaluation should be used to determine if additional studies are needed to more thoroughly determine thermal plume impacts.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

Entrainment and impingement impacts were assessed from April 1978 to April 1979 (PG&E 1982). As in similar 316(b) studies done at Potrero, Contra Costa, Pittsburg and Humboldt Bay power plants at roughly the same time, entrainment sampling was done at the discharge assuming that samples at this location would be "well mixed." At Hunters Point, a pipe was directed into the outer part of the discharge structure, and samples pumped through a 335 micron mesh net to collect the organisms to be counted and identified. A "mass balance" study was done comparing plankton in the intake and discharge. Samples at the two locations were taken for one hour at each of 8 times during 2 days. The results for the period sampled indicated mean plankton densities at the intake for all target organisms "considerably exceeded" mean discharge densities. Therefore, abundances of target organisms sampled at the discharge during the entrainment study were "scaled up" accordingly. PG&E (1982) did not determine whether the sampling location within either the intake ("mass balance" study) or the discharge ("mass balance" and entrainment study) adequately represented all organisms being entrained. Moreover, entrainment impacts were assessed assuming (based on field and laboratory studies; details not in report) that mortality from entrainment was only 25% (versus the current standard of 100%).

Velocities at the intakes in the intake basin range from 0.1 - 3 feet per second, the latter greatly exceeding the currently accepted BTA standard of 0.5 feet per second. Moreover, there was some suggestion that the intake system (conduits and intake basin) may act to trap fish. Impingement sampling (PG&E 1982) appears adequate, although now out-of-date given changes in the ecology of San Francisco Bay since 1978-79.

Conclusions

The methods used in the entrainment study produce results of unknown accuracy. Impacts based on PG&E (1982) are likely to be extreme underestimates due to the methods used and the assumption of only 25% mortality. Thus, the conclusion in PG&E (1982) of "no adverse impact," a conclusion which apparently the SFRWQCB continues to rely on in permitting this plant, is likely to be wrong. Moreover, fish populations have changed since the study was done.

A new 316(b) study needs to be done using currently accepted sampling methods and protocols, including source water sampling for ETM proportional loss estimates. This study should also include a cumulative impacts analysis since the Potrero Power Plant is nearby. A BTA analysis needs to be done on the cooling system.

Literature Cited

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HUNTINGTON BEACH GENERATING STATION

Background

The Huntington Beach Generating Station, located south of Los Angeles in Huntington Beach, draws cooling water from an intake pipe located approximately 1700 feet offshore and discharges heated water through a pipe approximately 1500 feet offshore (AEG 2002). The owner filed an AFC with the Energy Commission in 2000 to replace old units at the station. The adequacy of the information in the AFC and related documents concerning thermal, entrainment and impingement impacts were extensively discussed in Davis et al. (2001) and summarized below.

316(a) – Thermal Impacts

Existing studies (cited in Davis et al. 2001) are adequate to determine the distribution and biological impacts of the thermal plume.

316(b) – Impingement, Entrainment and Entrapment Impacts

Like the El Segundo Generating Station, a 316(b) entrainment study had never been done at this plant. Instead, a study done at the Ormond Beach Generating Station (see Ormond Beach review) was used as a surrogate, and the results scaled to Huntington Beach flow rates. There have also been considerable changes in fish populations in the Southern California Bight since this study was done more than 20 years ago. A new entrainment study was needed. This power plant has historically high impingement, so up-to-date data on impingement were also needed, along with an analysis of BTA for the cooling system. For these reasons, Davis et al. (2002) concluded that a new, well designed 316(b) study was necessary to adequately assess entrainment and impingement impacts, including a cumulative impact analysis. The new 316(b) study began in July 2003, sampling was completed in August 2004, and the draft final report submitted to the CEC in February 2005 (MBC/Tenera 2005). The report and possible mitigation for impacts are currently being reviewed by the CEC.

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LONG BEACH GENERATING STATION

Background

The Long Beach Generating Station is located in Long Beach Harbor, and withdraws cooling water from the back channel of the harbor. Heated water is discharged into the Long Beach Harbor Channel at Berth 114 (see AEG 2002, for details).

316(a) – Thermal Impacts

Description of thermal plume

Long Beach Generating Station discharges into the 500-1000 feet wide back channel of Long Beach Harbor (EQA/MBC 1973). The thermal plume was evaluated in 1972-73 by continuously recording surface temperatures with vessels, profiling temperature and oxygen versus depth and measuring temperatures at shore contact points in May and October 1972. A similar study was done in 1974-1978 (EQA/MBC 1978). The plant was running at much reduced capacity in October 1972 so the plume study was largely based on studies in May 1972. Delta T at the point of discharge can be up to 20 degrees F. EQA/MBC (1973) concluded that the resulting surface plume with delta Ts of 4 degrees F or higher extended 400 feet up the channel and 280 feet down the channel (including contact with the shore). Delta Ts of 1-2 degrees F contacted the bottom to depths of around 10 feet.

MBC (1996) sampled temperature, dissolved oxygen, and pH at 8 stations, one near the outfall, three in the inner harbor north of the outfall, and 4 at increasing distances away from the outfall towards the outer harbor. Sampling was done in March and September, 1996, at flood and ebb tide, to satisfy LARWQCB requirements. Such sampling continues, and has been done for many years (S. Beck, MBC Applied Environmental Science, pers. com.). The study found temperatures to be in the range of natural variation, and concluded there were no adverse effects of the discharge.

Effects of thermal plume

Benthic grab samples and trawls, and intertidal sampling were done in August 1972 and January 1973 and used to evaluate biological impacts of the thermal discharge. EQA/MBC (1973) concluded there were “no biological patterns that could be related to the discharge,” perhaps due to the intermittent operation of the power plant. EQA/MBC (1978) concluded the “generating station had no apparent adverse affect on water quality” even though sampling near the discharge revealed reduced diversity and abundance of hard bottom intertidal organisms, and an increase in ephemeral species when the plant was operating.

Conclusions

These 316(a) studies were generally well done, but given sampling designs, conclusions that there are no effects of the discharge are questionable. Moreover, the differences in delta T magnitude and extent between the findings of MBC (1996) and prior studies need to be resolved. Knowing the 3-dimensional distribution of the plume over a greater variety of operating conditions would assist the identification of potential impacts. Since the plume apparently does not contact the benthos below 10 feet, it is unlikely to affect deeper benthic organisms or highly mobile fishes. However, in most cases there was only one "impact" station, so rigorous statistical analyses is not possible. EQA/MBC (1973) had only 3 intertidal stations surveyed once in August 1972, and only one was within the region of 4 degrees F temperature increase. Differences near the discharge are attributed to other possible factors (e.g., toxic wastes and urchin grazing). A better sampling design is necessary for the conclusion of "no effects." EQA/MBC (1978) was better designed with more thorough surveys, but the ability of this study to detect discharge effects is questionable. A comprehensive review and re-analyses of the data in EQA/MBC (1973 and 1978) might help to better understand the impacts from this discharge, and indicate whether additional 316(a) studies are warranted.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

Similar to the Alamitos Generating Station, the 316(b) study for Haynes Generating Station (IRC 1981) was also used as a surrogate for an actual study at Long Beach (SCE 1982). The same design flaws, therefore, apply (see Haynes review). In the case of Long Beach, however, there is the additional problem that the intake is located in Long Beach Harbor, not Alamitos Bay, and there were no rigorous comparative studies done to show the composition and abundance of plankton in Alamitos Bay were the same as in Long Beach Harbor. An impingement study was done for Long Beach (SCE 1982) and appears adequate although out-of-date (1978-80) given changes in the ocean environment. However, intake velocities range from 0.4-1.34 feet per second, the upper ranges exceeding the currently accepted BTA of 0.5 feet per second or lower.

EQA/MBC (1978) did an "entrainment" study at the generating station; however the study objective was to determine "mortality associated with station transit," primarily for two copepods, not to thoroughly assess the overall effects of entrainment on larval populations.

Conclusions

A properly designed entrainment study has never been done for the Long Beach Generating Station, and needs to be done if the entrainment impacts of this power plant are to be known.

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LOS ANGELES HARBOR GENERATING STATION (HARBOR STEAM PLANT/HARBOR GENERATING STATION)

Background

The Los Angeles Harbor Generating Station is located in Los Angeles Harbor. The plant draws water from the East Basin, and discharges heated water through a pipeline into the West Basin (see AEG, 2002, for details).

316(a) – Thermal Impacts

Description of thermal plume

The 316(a) study for this plant was done from November 1971 to November 1972 (WEI 1973). Five quarterly temperature surveys were done at 11-12 stations, consisting of continuous surface and near bottom horizontal temperature measurements. The delta T at the discharge is 12-15 degrees F. The study concluded the plume impacted the upper 10 feet of the water column in the West Basin. Bottom temperatures increased by no more than 2 degrees F in the inner harbor. The 1 degree F delta T surface water isotherm was within 600 feet of the discharge. No studies of temperature increases at the shoreline were done.

MBC (1996) sampled temperature, dissolved oxygen, and pH at 3 stations at increasing distances from the outfall in March and September, 1996 at flood and ebb tide to satisfy local LARWQCB requirements, and this sampling continues. Findings were similar to WEI (1973), and the study concluded “water temperatures were higher in the summer than the winter, differences were slight among stations and between tides, and temperatures were elevated 2 degrees C above ambient in upper 6.6 feet of water at the site nearest the station during a summer flood tide.” Based on this and comparisons with previous studies, MBC (1996) concluded there were no adverse effects of the outfall.

Effects of thermal plume

The only effects of the plume on the biological environment were those determined based on benthic grab samples at 6 sites in the middle of the channel and extending away from the outfall, and some qualitative SCUBA surveys of the epifauna (WEI 1973). The study concluded that diversity, biomass, etc. increased with increasing distance from the outfall, but the differences were “not significant.” However, no rigorous statistical analyses were done to test this conclusion, and it is admitted in the report (WEI 1973) that the data were “not adequate to detect a discharge effect.”

Conclusions

The thermal plume from this discharge appears to be fairly localized. However, the effects in this local area have not been well studied, and no studies have been done of effects of the plume contact on the shoreline. New Receiving Monitoring Studies are now available (2004; S. Damron, LADWP, pers. comm.) that were not reviewed. They need to be reviewed along with previous studies to determine if thermal impacts have now been adequately determined.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

The only entrainment study at this plant is reported in IRC (1981). The approach used was the same as that for Haynes Generating Station (see Haynes review) and, therefore, has the same potential inaccuracies. In addition, this and the Haynes study used dye experiments to define the “source water,” the volume of water in the vicinity of the intake that is subject to entrainment (“probability of entrainment”). This approach does not define source water as the term is currently used: the water containing larvae of a particular species that are subject to entrainment. The dye approach does not consider variation in the length of larval life, mobility of larvae, and temporal variation in larval production. However, the study nevertheless concludes that entrainment and impingement “have no significant impacts on population abundances.” The impingement portion of IRC (1981) appears adequate. However, intake velocities are 1 feet per second, higher than the currently accepted BTA of 0.5 feet per second or less.

Conclusions

See also details in Haynes review. A new 316(b), using modern sampling and analytical approaches, is needed at this plant to provide an accurate estimate of current entrainment impacts. The cooling system needs to be re-evaluated for BTA.

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WEI (Woodward-Envicon, Inc.). 1973. Thermal effect study at the Harbor Steam Plant. Woodward-Envicon, Inc., San Diego. (not consecutively paginated).

MANDALAY GENERATING STATION

Background

The Mandalay Generating Station is located near the City of Oxnard in Ventura County. It draws water, via a 2.5 mile long canal, from the Channel Islands Harbor located south of the power plant, and discharges heated water via a rock lined canal onto the sandy beach directly west of the plant (detailed site description in AEG 2002).

316(a) – Thermal Impacts

Description of thermal plume

Thermal plume and related studies at this generating station have been reported in PNL (1972), SCE (1973) and MBC (1996). PNL (1972) reported delta T's at the discharge at between 21.3 and 31.3 degrees F. Using aerial infrared photography and in situ temperature profiling, PNL (1972) estimated the average area of the plume to a delta T of 2 degrees F to be around 150 acres (scaled from Fig. 21 in PNL 1972) and elevated temperature to occur to a depth of 5-15 feet SCE (1973) reported a very low delta T for the discharge (<1 degrees F), but the discharge is into the surf zone, and the station used to determine discharge temperature was outside the surf zone. Sites were also sampled (surface and temperature profiles) within a 1000-foot radius semi-circle centered on the discharge. During one survey, surface temperatures within this semi-circle were 4 degrees F warmer than at a control site. Profiles indicated elevated temperatures on the bottom only in the "littoral zone" (presumably this is the intertidal zone, up to 9 feet deep at high tide). MBC (1996) determined temperatures around the discharge and came to similar conclusions. Unfortunately, the closest shore stations to the discharge station were approximately 1000 feet north and south, so the length of shore that is thermally impacted was not well defined. No 3-dimensional model of the thermal plume based on all individual surveys was produced.

Effects of thermal plume

The effects of the thermal discharge on marine communities were studied only by SCE (1973) using fish trawls, benthic grab samples, intertidal surveys, and qualitative SCUBA observations. Sampling was done quarterly from December 1971 to November 1972. Fish trawls were done at 4 stations near the discharge (two at the 20 feet and two at the 30 feet depth contours) and 4 stations at similar depths away from the discharge. Since thermal impacts appear to occur only in the littoral zone, these stations are not impact stations, and the results irrelevant to impact analyses. Benthic grabs were done at the same stations and are, therefore, also irrelevant to an impact analysis. Beach sampling along transects perpendicular to the shore was done at stations beginning 100 to 300 feet from the discharge and extending north and south. None of the sites were at the discharge. Samples along transects “to the waters edge” were sieved through 3 mm mesh, and animals identified and counted. Transects were apparently not standardized to tidal height. The sieve size is large relative to current methods used in recent 316(a) studies at Morro Bay (1.5 mm mesh; DUKE 2001). SCE (1973) admitted that these intertidal sampling techniques probably underestimated population densities of beach infauna. In addition, lack of replication makes it difficult to determine if variation among stations was due to sampling or real differences. In short, the study design was such that the accuracy of the results are unknown.

Conclusions

The 316(a) studies are not complete enough to thoroughly determine thermal impacts. To guide the assessment of possible biological impacts, existing temperature data should be integrated into a 3 dimensional model of the plume, with isotherms showing probability of delta T’s to as low as 2 degrees F. This model could be used to help design studies such as those recently done at Morro Bay (DUKE 2001) to determine impacts on the sandy beach and shallow subtidal benthic fauna.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

The 316(b) study for the Mandalay Generating Station is reported in SCE (1982). As part of the “representative site concept” used at the time, entrainment sampling for Mandalay was not done at Mandalay Generating Station but, because of presumed similarities of intakes in ‘bays and harbors,’ the sampling and results from Haynes Generating Station reported in IRC (1981) were used to estimate entrainment impacts at Mandalay Generating Station by simply scaling to the Mandalay Generating Station flow rates. Since the Haynes study used a sampling design of unknown accuracy (see Haynes review), the Mandalay entrainment study is also of unknown accuracy. In addition, since the Mandalay Bay intake in Channel Islands Harbor is a considerable distance north of Haynes, there is little reason to think that the composition and abundance of the plankton at the two locations are similar enough to provide an accurate assessment of entrainment impacts. SCE (1982) provides few data showing that plankton communities are suitably comparable. The study is also now over 20 years old and the natural fish fauna has no doubt changed significantly since the original study was completed.

Impingement was adequately assessed at Mandalay in 1978-1980, and has been assessed bi-monthly since May 2001 (K. Whelan, Reliant Energy, pers. comm.). These recent impingement studies were not reviewed. Intake velocities vary between 0.01 and 3 feet per second (SCE 1982).

Conclusions

Entrainment has never been directly assessed at the Mandalay Generating Station, so environmental impacts are unknown. A complete, modern 316(b) study needs to be done at this plant, along with a BTA analysis of the cooling system.

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SCE (Southern California Edison Co.). 1982. Mandalay Generating Station 316 (b) demonstration. Southern California Edison Co., Rosemead. 28 pp. + appendices.

MORRO BAY POWER PLANT

Background and Conclusions

The Morro Bay Power Plant withdraws seawater for cooling from an intake just inside the entrance to Morro Bay, and discharges heated water into a short discharge canal that empties into the open coast intertidal zone north of the plant where the rocky intertidal of Morro Rock meets a sandy beach (AEG 2002). The power plant owner filed an Application for Certification with the Energy Commission in 2000 to permit power plant modifications. The owner initiated discussions with the CEC, CCRWQCB and other relevant agencies in a Technical Working Group format prior to 2000, and the Technical Working Group recommended that new 316(a) and (b) studies using currently accepted sampling designs and analyses be done to properly assess present and post-modification environmental impacts associated with the once-through cooling system. Entrainment required a detailed analysis of circulation within Morro Bay and between Morro Bay and the nearshore open ocean, and included sampling at the intake and a source water stations in and outside the bay. The data were used to estimate impacts on adults (including those from impingement: AEL and FH) and larval populations (ETM to estimate proportional larval losses in source populations). The assessment of thermal impacts required new studies to detect possible thermal effects in all benthic habitats contacted by the plume. The design, implementation, data analyses and interpretation for all studies were reviewed by the Technical Working Group, and the studies have been completed (Duke 2001a, b). The environmental effects of the present and proposed future of this once-through cooling system are, thus, reasonably well known (reported in Duke 2001a, b).

Literature Cited

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MOSS LANDING POWER PLANT

Background and Conclusions

The Moss Landing Power Plant is located within the Moss Landing Harbor/Elkhorn Slough complex in Moss Landing, the coastal center of Monterey Bay. The cooling water intakes are located in Moss Landing Harbor, and discharge occurs through pipes under the harbor and sand spit, terminating approximately 600 feet off the shore of the open coast (AEG 2000; Duke 2000). Thermal plume distribution and environmental impact assessments done for this plant prior to 1999 were carefully reviewed by a Technical Working Group established by the CCRWQCB when the owner applied to the Energy Commission and CCRWQCB for operating and discharge permits associated with a proposed plant modernization project. The Technical Working Group was composed of Energy Commission and CCRWQCB staff and consultants familiar with the local environment and the design and evaluation of 316(a) and (b) assessments, representatives from other interested agencies (e. g., CDFG, CCC) and the plant owner. Additional consultants participated as needed to fully evaluate the technical issues. The Technical Working Group determined that prior 316(a) and (b) studies for the plant suffered from many of the problems noted for most power plants in this review, and did not accurately describe impacts of either the old or the proposed, modernized cooling system. The owner agreed to do new studies which were completed in 2000 (Tenera 2000, Duke 2000).

Thermal effects were evaluated and, because the amount of water discharged would increase after modernization, the characteristics of the plume after modernization were predicted (Duke 2000). The owner is also completing a thorough study of the new thermal plume now that the modernized plant is operational. These thermal effects studies were solely to characterize the 3-dimensional distribution of the plume under a variety of operating and oceanographic conditions. The present plume, and certainly the new plume, contact intertidal rocky, intertidal sandy and subtidal benthic habitats. The Technical Working Group, however, concluded it would be difficult if not impossible to separate the biological effects of the thermal plume from other anthropogenic impacts in the near vicinity, especially those from the discharge of dredge spoils from Moss Landing Harbor. Thus, no studies of thermal impacts were recommended or undertaken.

Impingement by the modernized plant was reduced with modifications to the intake structures (Tenera 2000). The plant owner is contributing towards habitat restoration in and around Elkhorn Slough to compensate for entrainment and impingement impacts, and monitoring studies related to the new discharge. This “mitigation” is being done with oversight from the Energy Commission and CCRWQCB.

Literature Cited

AEG (Aspen Environmental Group). 2002. Moss Landing Inventory and 316(a) and (b) Summary. In: Coastal Power Plant Inventory - Plant Facility and Operational Data. CD ROM prepared for the California Energy Commission.

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ORMOND BEACH GENERATING STATION

Background

The Ormond Beach Generating Station is on the open coast beach in Ventura County, with an intake located approximately 2000 feet offshore at 30 feet deep. Discharge also occurs offshore through an approximately 1800 feet long pipe. The intake and discharge are thus similar to those of Scattergood, El Segundo, and Huntington Beach Generating Stations (site details in AEG 2002).

316(a) – Thermal Impacts

Description of thermal plume

The SCE (1973a) report on thermal plume distribution is based on studies almost identical to those done for 316(a) at Mandalay (SCE 1973b). Additional thermal dispersion studies were done by EQA/MBC (1974). These studies showed that within a 1000-foot radius around the outfall, delta T's were 4 degrees F 23% of the time in one quarterly sampling. Thus, it is likely that the shore is at least occasionally impacted by water at a delta T of 4 degrees F or greater.

Effects of thermal plume

These studies were also similar to those done at Mandalay reported in SCE (1973b) except that the "impact" trawls for fish and invertebrates were close to the discharge, and no grab samples were taken. Additional studies were reported in SCE (1975). Trawl results for fish indicated no differences in diversity near and away from the outfall, with the 'away' stations more variable. The invertebrate trawls had a mesh size of 1.5 inches, so would only catch very large epifaunal invertebrates. The results of these trawls indicated no "apparent" effects of the discharge on sheep crabs or cancer crabs. There were more sand dollars in the control area, but abundances were also more variable in the control areas. Sandy beach surveys occurred along transects at varying distance from the discharge. They indicated no significant effects of transect location but there were few transects in the region of likely thermal contact.

Conclusions

Temperature distribution data from PNL (1972), SCE (1973a), and EQA/MBC (1974) should be compiled and used to produce a 3-dimensional map of the plume, contoured by delta Ts. This map could be compared with prior biological sampling locations to determine if further biological sampling is necessary. Even though sampling of the sandy beach was inadequate, the available plume data (if accurate) suggests that impacts to the sandy beach are probably minimal.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

The Ormond Beach intake is an offshore pipe with a velocity cap. Intake velocities are 2.7 feet per second. Entrainment and impingement studies for Ormond Beach are reported in SCE (1975, 1983). SCE (1975) primarily attempted to estimate entrainment mortality of phytoplankton and zooplankton. The study concluded there was no significant effect of entrainment on phytoplankton, and that zooplankton entrainment mortality ranged from 10-60% depending on temperature. However, the methods used to assess mortality (e.g. ATP, vital stains) indicate only that some living tissue is present, not that the organisms are unharmed and have the same survivorship and reproduction as individuals not entrained. SCE (1983) was the 316(b) study. In this study, entrainment samples were collected monthly from August 1979 to July 1980 by pumping samples from within the intake riser. This was done by inserting a metal standpipe through the velocity cap of the riser. This method assumes that such samples are unbiased estimators of what is actually entrained through the intake. To test this assumption, Schlotterbeck et al. (1979) compared such pump samples with samples downstream in an intake pipe at a position thought to represent homogeneous mixing (see also discussion of sampling methods in SCE 1982). The two samples were similar but not the same. Moreover, there were no biological sampling data to test the assumption, based on dye studies, that the region sampled downstream represented a region of homogeneously mixed larvae. The decision to do entrainment sampling in the riser was made only partly on its representativeness of what was actually being entrained (Schlotterbeck et al. 1979, p. 15). A further problem with this sampling approach is that the riser vs. downstream comparative study was done only at the intake of the San Onofre Nuclear Generating Station. While Ormond Beach has an intake of similar design, it is not the same. Therefore, it is essentially unknown how representative pump samples from the intake riser are of larvae entrained by the Ormond Beach Generating Station. Moreover, monthly sampling may miss short lived pulses of larvae - modern studies commonly sample every 2 weeks. This entrainment study is more than 20 years old, and even if the entrainment results were accurate, natural changes have occurred such that the results are no longer useful to assess current impacts.

Impingement was sampled from October 1978 through September 1980, and sampling appeared to be adequate. Impingement sampling is ongoing (K. Whelan, Reliant Energy, pers. comm.), but studies since 1980 were not reviewed.

Conclusions

The accuracy of estimated entrainment is unknown. A new, modern 316(b) entrainment study needs to be done at this plant, and the cooling system evaluated according to current BTA.

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PITTSBURG POWER PLANT

Background

Units 1-7 of the Pittsburg Power Plant draw “fresh to brackish water” from the southern shore of Suisun Bay (San Francisco Delta) at the city of Pittsburg, and discharges it back through conduits at 20-25 feet depths near the shore (PG&E 1992; additional site description in AEG 2002).

316(a) – Thermal Impacts

Description of thermal plume

The original 316(a) study for this plant was done in 1972 (PG&E 1973). Plume distribution was determined using the same methods as for the Hunters Point Power Plant. Delta Ts ranged from 15-19 degrees F, producing a plume that was 1100 feet long and 2000 feet wide, covering an average area (at or above a delta T of 4 degrees F) of 50 acres. Vertical temperature profiles were done, but the extent of plume contact with the bottom was not determined except “temperature increases at depth were confined to the immediate vicinity of the discharge.”

PG&E (1992) also examined the distribution of the thermal plume. The discharge delta Ts were 15 degrees F for Units 1-4, and 17 degrees F for Units 5 and 6. The plume covered 8 to 91 acres, and occurred to 4000 feet offshore. It contacted over 1000 feet of shoreline and the bottom to 500 feet offshore and occasionally extended into the lower portion of nearby New York Slough.

Effects of thermal plume

Biological sampling was done in 1972 using a study design similar to that used at Hunters Point Power Plant (PG&E 1973). Five fish sampling stations were used. The report admits the station most distant from the plant was not a true control, but “not usually influenced by the plume.” Benthic grab samples were done at 10 stations, and the results correlated with surface temperature to determine possible discharge impacts. As for Hunters Point, Contra Costa and South Bay Power Plants, this “test” of impact is inappropriate because plume distribution can be highly variable – what is needed is correlation with average bottom temperatures.

PG&E (1992) sampled large organisms inside and outside the thermal plume from July 1991 to June 1992. Sampling was done monthly, but time of day was not specified. The study primarily focused on whether or not plankton and nekton populations differed inside and outside the plume. The results indicated similar species and abundances of fishes inside versus outside, but more shrimp (*Crangon franciscorum*) outside the plume. Sampling with 500 micron mesh nets examined effects on plankton. Again, time of day was not specified, and the sampling program is not described in sufficient detail to determine how well it could detect impacts. Even though the plume contacts the shore and the subtidal benthos, no surveys of these habitats were done.

Conclusions

More temperature measurements, especially vertical profiles, across the range of plant operating, river flow, and seasonal conditions are needed to characterize the 3-dimensional distribution of the thermal plume. This plume model should be used to determine the magnitude and extent of thermal impact on all habitats affected by the plume. Prior biological surveys need to be carefully reviewed to determine if the thermal effects on plankton, nekton and the benthos are well determined and new surveys done as appropriate to fully characterize thermal impacts. Apparently the intake for this plant is being evaluated, and a new thermal effects study will be done after a decision is made on the design of a new intake (G. Chammas, Mirant, pers. com.).

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

The 316(b) study for this plant, done in 1978-1979 (PG&E 1981), was similar in design to that used at other PG&E power plants in the region – pump sampling from the discharge through a 505 micron mesh net. "Mass balance" studies at Pittsburg suggested that the abundance of target species was similar at the intakes and discharges. This was determined by a statistical comparison of 30 samples taken over 6 different days. However, a power analysis on the data was not done, so it is not known what difference would have been detectable. Moreover, the bias of pumping from a particular place in the discharge (versus across the entire discharge) is not known. Source water sampling was not done, precluding ETM analyses. The accuracy of the entrainment impact estimate is, therefore, unknown.

Because of concern for negative impacts on striped bass populations (even though striped bass is an introduced species), there is ongoing sampling at Pittsburg to determine impacts on striped bass populations and apparently plant operations have been modified to reduce egg, larval and juvenile mortality (PG&E 1982; an analysis and discussion of these modifications was beyond the scope of this review). PG&E (1993) discusses entrainment monitoring for striped bass only in May - July, 1993. No details on mesh size, etc. were given. The results of the sampling were scaled up to entrainment impact using pumping rates. PG&E (1998) summarizes prior 316(b) studies, and indicates sampling for striped bass larvae in May-July was done from 1984-1993. The impingement study in PG&E (1981) appears adequate, but is now out-of-date.

Conclusions

The accuracy of the original 316(b) study (PG&E 1981) is unknown as a result of sampling methods, including discharge sampling from a particular location with a pump. It is now also out-of-date. A new, well designed 316(b) study needs to be done for this plant, along with a determination of BTA for the cooling system. Such a study has been required for this plant by the SFBRWQCB (G. Chammas, Mirant, pers. com.).

Later studies have focused primarily on striped bass. These studies need thorough, rigorous review by entrainment and fisheries experts to determine how well they estimate the effects of entrainment and impingement on striped bass populations in the source water.

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POTRERO POWER PLANT

Background

The Potrero Power Plant is located on the western shore of South San Francisco Bay approximately 2 miles south of the western end of the Bay Bridge (detailed site description in AEG 2002). The owner wanted to modify the plant, and filed an Application for Certification with the Energy Commission in 2000. Energy Commission staff reviewed the relevant 316(a) and (b) information in the AFC and found it insufficient to accurately determine the effects of the present cooling system or predict the effects of the new system. This review, along with relevant citations, is summarized in Davis et al. (2002).

The plant cooling system has been routinely permitted by the SFRWQCB. Davis et al. (2002), however, found that the sampling used to conclude no adverse environmental impact was inadequate to accurately determine 316(a) (the unmodified plant discharges into the intertidal zone) or 316(b) (the existing power plant's intake is on the shoreline) environmental impacts. Among other problems, prior 316(b) studies at Potrero Power Plant estimated entrainment mortality by sampling the discharge rather than around the intake, resulting in a biased estimate of entrainment. As a result of Energy Commission data requests based on the AFC, a new 316 (b) study was done by the applicant using currently accepted sampling designs.

316(a) – Thermal Impacts

The project owner reported the results of 316(a) related surveys and data analyses in Tenera (2000), and Mirant (2001, 2002). A complete 316(a) analysis remains to be done.

316(b) – Impingement, Entrainment and Entrapment Impacts

As a result of Energy Commission data requests, a new 316(b) entrainment study using currently accepted methods was done January 2001 - December 2002. The report on this study was recently submitted to the SFRWQCB and is being reviewed.

Conclusions

While the plans to modify this plant have been withdrawn, the new thermal and entrainment information could be used to more accurately determine impacts to the marine environment from the existing plant. The 316(b) information should also be useful to scientists and agencies (e.g. CDFG, NMFS, SFBRWQCB) in assessments of the planktonic environment of South San Francisco Bay. Adequate 316(a), impingement, and cumulative studies are needed to accurately understand the impacts of this plant on the environment of South San Francisco Bay.

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REDONDO BEACH GENERATING STATION

Background

The Redondo Beach Generating Station is located in King Harbor at the southeastern end of Santa Monica Bay. Scattergood and El Segundo Generating Stations also use Santa Monica Bay water for cooling. The Redondo Beach Generating Station uses two cooling systems, with separate intakes and discharges for each. Two generators (Units 5-6; Units 1-7 are out of service) intake water from the central portion of King Harbor near the breakwater and discharge it at a delta T of 23 degrees F (max.) through 2 discharge pipes located 1600 feet offshore at a depth of 25 feet just outside the breakwater at the western end of the Harbor. The remaining 2 generators (Units 7 and 8) intake water through a pipe located near the eastern terminus of the breakwater, and discharge it at a delta T of 18 degrees F, 300 feet offshore but within the eastern end of the Harbor at a depth of 20 feet (SCE 1973). Additional site description can be found in AEG (2002).

316(a) – Thermal Impacts

Description of thermal plume

The primary 316(a) study for this plant was done between November 1971 and January 1973 (SCE 1973). Surface (including shoreline) and subsurface temperatures were determined in and outside King Harbor during quarterly surveys. The surface results are presented for each survey and as a composite of 4 degrees F and 1 degree F isotherms for all surveys. Subsurface temperatures were not as thoroughly surveyed, and no 3-dimensional thermal plume map was done.

Additional temperature, dissolved oxygen and pH monitoring was done in March and August 1996 by the City of Los Angeles (MBC 1996) and continues twice per year. This monitoring contributes little to understanding the plume because of the limited time and spatial extent of the work.

Effects of thermal plume

The plumes of elevated temperature from these discharges contact hard (breakwaters) and soft intertidal and subtidal bottoms in and outside King Harbor with delta T's of 4 degrees F and greater (SCE 1973; see Fig. 4-7). The effects of the plume in the subtidal zone were examined for benthic infauna (grab samples and diver observations) and subtidal fishes (trawls) at various stations inside and outside the harbor (SCE 1973). Plume effects on the intertidal zone were examined by surveying intertidal organisms along 4 transects on various breakwaters. Two transects were inside the harbor, and 2 outside. No studies were done of sandy beach fauna even though beaches are contacted by delta T's of 4 degrees F or more.

The report admits that the biological surveys that were done were not well designed to detect thermal impacts. Problems included time of sampling, number of stations, and replication. Apparently the study design was specified in advance by the LARWQCB with little consideration of what design would be best to determine impacts. The report states (p. 33), "Given satisfactory conduct of the specified study, the conclusions derived from the study must still be clouded with ambiguities resulting from normal variability that could have been avoided by designing a sampling program to answer the proper, specific questions." Trends in the data and other observations suggested the discharge affects the soft benthos, fish populations (including higher incidence of disease) and subtidal algae. Surprisingly, given these effects and the admitted poor study design, SCE (1973) nevertheless concluded (p. xiii) "the Redondo Beach Generating Station is in compliance with the Water Quality Control Plan." Apparently the LARWQCB accepted this as true, and continues to permit the plant even though the studies upon which the permits are based are admitted to be flawed by those who did them.

Conclusions

The plume description appears adequate for surface distribution, but not depth distribution. Existing data, combined with data from new thermal surveys under a variety of plant operating and oceanographic conditions, need to be used to develop a 3 dimensional map of the probability of a delta T of 2 degrees F or more for the entire region affected by the plume.

In addition to impacting a large portion of King Harbor, delta T's of 4 degrees F or higher from the discharge extend thousands of feet along the shore east and west of King Harbor, and thousands of feet offshore. Impacts are likely, and probably occur over a large area. Given the problems with prior biological surveys noted above as well as the qualitative evidence for thermal effects in these studies, new, rigorous biological surveys need to be done to determine the magnitude and extent of impacts from these discharges on marine communities.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

The 316(b) entrainment study was done from August 1979 through July 1980 (SCE 1983) using samples collected during one 24 hour day/month by pumping water from the intake riser. The sampling method was based on pilot studies at the San Onofre Generating Station Unit 1 intake (SCE 1982). These same pilot studies were also used as the basis for pump sampling at Ormond Beach during the same time. As discussed in the Ormond Beach review, it is highly uncertain how well this method samples plankton being entrained. Therefore, how representative pump samples from the intake riser are of larvae entrained by the Redondo Beach Generating Station Intakes is essentially unknown.

Impingement sampling appears adequate but recent studies need review. Intake velocities for the Unit 7 and 8 intake averaged 2.7 feet per second in 1983 (SCE 1983). Intake velocities for Units 1-6 could not be found in the reports reviewed.

Conclusions

Entrainment impacts estimated from available studies are no doubt highly inaccurate. A new, modern 316(b) entrainment study needs to be done at this plant, and the cooling system evaluated relative to current BTA.

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SAN ONOFRE NUCLEAR GENERATING STATION (SONGS)

Background

SONGS is located in northern San Diego County just south of San Mateo Creek. Units 2 and 3 (Unit 1 has been decommissioned) have intake pipes that are 18 feet in diameter and extend 2400 feet offshore. The discharge pipes taper from 18 feet to 10-14 feet in diameter. The discharge for Unit 2 terminates 8500 feet offshore and 6150 feet offshore for the Unit 3 discharge. The last 2500 feet of both discharge pipes are multiport diffusers that mix cooling water with the surrounding water. The 63 diffusers per pipe are angled offshore to increase the velocity of the discharge. Each unit can draw in seawater at a rate of 830,000 gallons per minute.

Permitting at SONGS is unique among power plants in California. Two agencies share jurisdiction: SDRWQCB and the CCC. Permitting is based on the Coastal Development Plan and NPDES requirements. There are fundamental disagreements between the CCC and SDRWQCB as to the effect of SONGS; the CCC concludes that there are significant impacts resulting from the operation of SONGS, whereas the SDRWQCB largely concludes that there are none. Earth Island recently sued under the assertion that the studies done by SCE to satisfy NPDES requirements for the SDRWQCB were inadequate and that there were indeed impacts under NPDES. The suit was settled and the proceeds were used to fund the Redondo educational facility and PEARL wetland institute headed by J. Zedler. The information contained in this summary relates to the CCC findings (MRC 1989). CCC findings were based on studies conducted under the Marine Review Committee (MRC) an independent entity charged with evaluating the impacts resulting from the operation of SONGS. This structure was and still is unique in California. The studies were done on the basis of the coastal development permit, and were interpreted under NPDES regulations (as discussed below). Studies were generally based on a BACIP design (Before After Control Impact Paired) developed for the SONGS project.

316(a) (CCC; based on MRC Findings on Water Quality (MRC 1989)

To assess the effects of Units 2 & 3 on marine water quality the MRC collected data on the following water quality indicators for receiving waters:

1) Temperature: SONGS Units 2 & 3 were in compliance with NPDES permit limits (thermal plume monitoring was also done by SCE)

a. No increase in shoreline or substrate water temperatures over 4 degrees F.

b. Discharge delta T less than or equal to 20 degrees F.

c. Surface water temperature did not increase by more than 4 degrees F beyond 1000 feet from discharge system.

2) Metals Concentrations: Units were in compliance with NPDES limits for discharge of metals

3) Sediments: The data collected on sediment deposition in the vicinity of the discharge were inconclusive regarding compliance with NPDES permit limits for sediments. The evidence suggested that the operation of SONGS contributed to the presence of muddy sediments in the San Onofre Kelpbed (SOK). However, it did not conclusively support this hypothesis.

4) Natural Light Penetration (Turbidity): SONGS Units 2 & 3 were not in compliance with NPDES permit levels. The NPDES permit prohibits discharges that significantly reduce the transmittance of natural light at any point outside the area of initial dilution. The MRC found that light at the bottom of SOK was 6 to16% lower than it would have been in the absence of SONGS.

5) Marine Organisms: SONGS Units 2 & 3 were not in compliance with NPDES requirements governing impacts to marine life. The NPDES permits required that SONGS discharges be designed and operated in a manner that will maintain the indigenous marine life and a healthy and diverse marine community and that marine plant, vertebrate and invertebrate communities not be degraded. At SOK the MRC found that statistically significant SONGS-induced declines in populations of giant kelp (60%), kelp-bed fish (70%), kelp-bed invertebrates (30-90%), and some midwater fish species (as large as 70%). Most of these effects were attributed to the discharge plume (mainly via increased turbidity). Benthic fish, plankton, some species of mysid shrimp, and intertidal sand crabs were evaluated and did not show adverse effects from the discharge.

316(b) (CCC) – Impingement, Entrainment and Entrapment Impacts

The MRC also evaluated effects due to entrainment and impingement. For entrainment they used an adult equivalent model to determine impacts. In this model they calculated the effect on the standing stock of fish, where the geographic extent of the stock was assumed to be the Southern California Bight. The estimated loss to standing stock due to entrainment was considered to be “substantial” and ranged from nearly 0 to 13% (queenfish). Impingement losses were also considered to be substantial and have averaged about 23,000 kg (~ 50,000 lbs.) per year through 2002.

Mitigation (CCC 1991, 1996)

Mitigation was required to compensate for the impacts at SONGS. The following is a list of requirements (Conditions A-D of the Permit):

1) Wetland Restoration Mitigation (Condition A) – The general condition under this mitigation was to: (a.) restore 150 acres of wetland from a site nearby to SONGS (from a list of 8 sites). This requirement was later modified based on an inlet opening model that provided 35 acres of credit for inlet opening. The new requirement is for 115 acres. The selected site was San Dieguito Wetland. No construction has yet occurred. An EIR has been filed on the wetland restoration plan. There is currently a lawsuit pending to stop the restoration (filed by homeowners worried that the restoration will affect scour and undermine their houses) and (b.) performance will be assessed relative to standards in the permit (generally relative to uncompromised wetlands). This condition was largely to compensate for entrainment.

2) Behavioral Barrier Mitigation (Condition B) – the condition requires the testing of behavioral barriers in the intake system that could reduce impingement. The tests that were run indicated that neither lighting modification nor sound would reduce impingement. The condition was considered satisfied as long as the plant owner used a modified Heat Treatment in conjunction with the Fish Return System (unique to SONGS). This combination reduces impingement by about 80%, and was to compensate for impingement.

3) Kelp Reef Mitigation (Condition C) – general condition is to construct a reef that will provide 150 acres of medium to high density kelp and associated organisms. Performance is evaluated (generally) relative to control natural reefs, although numeric standards exist for kelp and fish production. This condition was to compensate for discharge effects at SOK. Currently there are 56 test modules in the water (40 by 40 meters) that were set up as an experiment to assess the effect of rock cover and material (rock vs. concrete) on reef performance. The build out reef is expected to be placed in the water in 2005-2006.

4) Administrative Structure (Condition D) – This condition set up the structure of the group responsible for ensuring that conditions A-C would be carried out and that the mitigations were effective. Independent scientists would run the mitigation program (technical staff), and a scientific advisory panel (SAP) would oversee the program. The responsibility for mitigation construction and design was and is in the hands of SCE, but the responsibility for monitoring and evaluation of effectiveness of the mitigation requirements is in the hands of the technical staff and SAP. Funding comes from SCE. There is a remediation requirement if the mitigation projects do not work. Monitoring and performance requirements will continue for the life of the plant. Cost estimates for the mitigation requirements range between $60 – 200 million.

316(a) and (b) (SDRWQCB NPDES permitting)

316(a) and (b) studies were done in the mid 1980's. The findings of these studies differed from those of the MRC (see above), and an NPDES operating permit was issued (under the finding that SONGS was in compliance with NPDES requirements). Since then the NPDES permit has been renewed regularly – the last time in 1999, and it is due for renewal in 2004. A number of exceptions have been granted over the last 20 years, the last in 1999 (SDRWQCB 1999), which increased the temperature allowed at point of discharge to 25 degrees F. As part of its NPDES permit SCE is required to produce an "Annual marine environmental analysis and interpretation." These have been produced since 1982 (e.g. SCE 2002). Each report contains an update on the studies performed by SCE as part of their NPDES permit. The sections include: (1) Study Introduction and generating station description, (2) Oceanographic processes and water quality, (3) Kelp density study, (4) In plant fish assessment (impingement), and (5) Fish population study.

General conclusions

The MRC evaluation done at SONGS was the most comprehensive investigation of impacts to the marine environment ever done for a power plant. The estimated cost of the evaluation was $50 million. The methods developed were and are state of the art (although a different model allowing for the use of ETM for evaluation of entrainment effects would be used today).

Possibly the most important aspect of SONGS was that independent scientists ran the evaluation program for impacts and are running the evaluation program for mitigation. In addition the requirement for remediation if the mitigation projects fail ensures compensation for lost resources. This approach should be a model for evaluation and mitigation of power plants.

While the SDRWQCB has continued impingement studies over the period of operation of SONGS, no additional entrainment or thermal studies [in the 316(a) and (b)] context) have been required by the SDRWQCB since the mid 1980's (note SCE has continued its own monitoring program – largely looking at effects on the kelp bed). Much has changed over the last 20 years, in terms of what is considered adequate for 316(a) and (b) studies and also in the environment. As an example, there is ample evidence that fish abundance and composition have been greatly altered. Hence, the initial studies currently used by the SDRWQCB are insufficient to fully evaluate the current impact of the operation of SONGS on the marine environment.

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SCATTERGOOD GENERATING STATION

Background

Scattergood Generating Station withdraws water from approximately 1500 feet offshore at a depth of 30 feet and discharges heated water approximately 1000 feet offshore at a depth of 27 feet (MBC 1996; further station details in AEG 2002). The station is 0.5 miles north of the El Segundo Generating Station.

316(a) – Thermal Impacts

Description of thermal plume

MBC (1996) monitored some oceanographic parameters near Scattergood Generating Station in 1996. However, the monitoring stations (specified by LARWQCB) were well away from the intakes and discharges, so the results cannot be used to evaluate thermal effects. Similar monitoring was done in 2000 (MBC 2000). Water quality monitoring continues, and new stations have been added to better document the extent of the thermal plume (S. Beck, MBC Applied Environmental Sciences, pers. com.). The documents examined and AEG (2002) suggest some description of the thermal plume and its impacts may have been done in the early 1970's, but no citations were provided and the report could not be found.

Effects of thermal plume

At the time of this review no studies of the effects of the thermal plume on nearshore marine communities could be found (see above).

Conclusions

From the documents available, little is known about the thermal plume from this plant or its effects on nearshore marine communities. There was insufficient time available to contact the station, arrange a visit and search its library for other reports. However, the setting of this discharge is similar to that of Huntington Beach and El Segundo Generating Stations. The 316(a) studies at these plants suggest plumes from such discharges have little contact with the benthos or beaches, and their overall effects on the environment are small. Therefore, similar small effects might be expected at Scattergood Generating Station.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

The primary 316(b) study for Scattergood is IRC (1981). The generating station is very close to El Segundo Generating Station, and the two stations have similar intakes and discharges. In light of this and that a 316(b) study had never been done at El Segundo, the owner of El Segundo argued in their recent AFC and at recent Energy Commission hearings that IRC (1981) could be used instead. To evaluate that argument, Energy Commission staff carefully reviewed IRC (1981) and found it had “a number of serious scientific problems,” particularly with sampling methods, and concluded most concentration estimates for larval fish used in the Scattergood analysis are highly unreliable (Davis et al. 2002; see Davis et al. 2002 for detailed discussion).

Intake velocity at the velocity cap is 1.5 feet per second. A review of IRC (1981) suggests that impingement was only measured during heat treatments. MBC (2000) also determined impingement but, again, only during heat treatments and the review in MBC (1997) also suggests that a complete impingement study (normal operation and heat treatment) has never been done at this station.

Conclusions

Similar to other generating stations located on Santa Monica Bay, the 316(b) assessments for the Scattergood Generating Station are of questionable accuracy. It also appears that a complete impingement assessment has never been done at this station. Intake velocities are high. A new, complete 316(b) study, including impingement under normal operating conditions, an assessment of cumulative impacts and a BTA analysis needs to be done. Given the need for a similar study at El Segundo and the proximity and similarity of the cooling systems at the two plants, a single entrainment study with entrainment sampling at either intake systems (or perhaps only one depending on the results of a well designed pilot study) might be suitable and cost effective.

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SOUTH BAY POWER PLANT

Background

The South Bay Power Plant cooling water system is unique in that the intake and discharge are both in a shallow (generally <18 feet deep) bay, the south end of San Diego Bay (see description in AEG 2002). In addition, San Diego Bay has been extensively altered by other anthropogenic activities, particularly effluent discharges that include sewage and industrial wastes. Most of these discharges were eliminated by 1963; however the power plant began operation of one unit in 1960, and had four units operating by 1972. Thus, power plant operation overlaps the period of changes in waste discharge, confounding attempts to determine the effects of the power plant discharge alone. Moreover, the thermal discharge affects a large portion of southern San Diego Bay, including the water that enters the intake.

The marine environmental impacts of the cooling water system were reviewed by Foster (1994). New 316(a) and (b) studies were recently completed (DUKE 2004).

316(a) – Thermal Impacts

Description of thermal plume

The discharge exits the plant via a “cooling channel” directly into the southern-most portion of the bay. Its spread into the bay is greatly influenced by the tide (Magdych, 1993). On an outgoing tide, a large portion of south San Diego Bay is affected - the region is essentially used as a large cooling pond. Numerous habitats are exposed to elevated water temperatures, including marsh, intertidal and subtidal soft benthos, and eelgrass beds.

Effects of the thermal plume

The recent DUKE (2004, Vol. I) report concluded that the thermal discharge causes the loss of ~ 42 hectares of eelgrass and its associated species, alteration of infaunal assemblages near the discharge, and alteration of fish assemblages in the discharge canal.

316(b) – Impingement, Entrainment and Entrapment Impacts

Existing information

A 316(b) study was done more than 20 years ago (Dietz, 1980). The study was reasonably well designed and revealed some large entrainment impacts, but did not combine entrainment and impingement losses to estimate overall effects on source water populations (Foster, 1994). Most larvae were not identified to species.

The new 316(b) study was recently completed at the request of the San Diego Bay Regional Water Quality Control Board (DUKE 2004, Vol. 2). This study was done over two years (2001-2003) using modern sampling and analytical approaches.

Conclusions

While DUKE (2004) has not been critically reviewed by independent experts, these studies clearly show this power plant has large thermal and entrainment impacts on southern San Diego Bay. The SDBRWQCB issued a new NPDES permit for the plant that only mentions the need for "abatement" of some of these impacts. What, if any, abatement may be done is currently unknown (H. Navrozali, pers. comm.).

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APPENDIX B: AUTHOR RESPONSES TO REVIEWER'S COMMENTS ON FOSTER (2005)

RESPONSES TO PUBLIC COMMENT ON FOSTER, M., "AN ASSESSMENT OF THE STUDIES USED TO DETECT IMPACTS TO MARINE ENVIRONMENTS BY CALIFORNIA'S COASTAL POWER PLANTS USING ONCE-THROUGH COOLING - A PLANT-BY-PLANT REVIEW" Draft Report February 2005 CEC-700-2005-004-D

by: Dr. Michael Foster, Moss Landing Marine Laboratories

<u>Industry Comments</u>

Susan M. Damron, Manager of Wastewater Quality Compliance, Los Angeles Department of Water and Power (Letter, April 11, 2005) - Comments 1 - 20.

1. Comment: Chose to review only three documents, 1973 thermal effects studies, 1981 316(b) study, and 1996 Receiving Water Monitoring (RWM) study. Other RWM reports were not reviewed. As a result, reviews are insufficient, incomplete and lead to inaccurate conclusions.

Response: The relevant power plant is not mentioned, but the document dates given suggest it is Alamitos. If so, the documents mentioned, especially the thermal and 316(b) reports, are the "core" studies for this power plant. As discussed in the Introduction to the Assessment Report, RWM studies done after the core studies are commonly only a partial repetition of the original studies. While not all were reviewed, those that were did not improve understanding of impacts.

2. Comment: Often concludes that a study or portions of a study are inadequate, however, the document never offers a definition, nor describes in detail, what is considered adequate.

Response: What is considered adequate, with general examples, is described in the Introduction to the Assessment Report. The portion of the Introduction describing this was revised for additional clarity.

3. Comment: Fails to describe the regulatory protocols used for the Thermal Effects Studies and the 316(b) Demonstration Studies that serve as the basis for the study design. The 1971 Thermal Plan was to require that existing dischargers

of thermal waste to conduct a study, and the Study Plan was developed by the LARWQCB with concurrence of the California Department of Fish and Game.

Response: The study designs were reviewed, and presumably reflect the protocols developed by the LARWQCB in concurrence with the California Department of Fish and Game. That regulatory protocols and report reviews were developed and done by regulatory agencies does not necessarily mean that the protocols resulted in accurate and comprehensive impact determinations or that the conclusions in reports on the studies (upon which permits are based) necessarily follow from the sampling designs used, data obtained, or analyses done.

4. Comment: While more recent entrainment and impingement approaches have been implemented, these neither invalidate not diminish the validity, accuracy, and usefulness of the data that was historically gathered. The fact that recent studies using currently accepted methods (as outlined in the Introduction) have been recently completed does not necessarily provide a greater understanding of the impacts than was known historically.

Response: The approaches may not alter the validity, etc. of historical data that were obtained, but in many cases they do. Furthermore, with the sometimes exception of impingement, all recent (as defined in the Introduction) studies have provided a much greater understanding of impacts. See, for example, the most recent thermal effects study done for Diablo Canyon Nuclear Power Plant, or the recent 316(b) study done for Morro Bay Power Plant.

5. Comment: The document questions the appropriateness of using "surrogate" studies. In the Phase II 316(b) Rule, EPA acknowledged the possibility for using surrogate studies.

Response: This certainly is possible depending on intake locations. See report conclusion for Alamitos and Scattergood Generating Stations.

6. Comment: The report states: "Sampling methods (e.g., sampling at the intake or discharge with a pump) likely provide biased estimates of entrainment." The currently used method of sampling with nets could also introduce bias if not properly integrated and accounted for. IRC (1978) accounted for this sampling technique (pump sampling) in its estimates of entrainment.

Response: Nets can also produce bias, but this has been assessed and methods developed to minimize it (see recent 316(b) report for Diablo Canyon Nuclear Power Plant). Presumably IRC (1978) refers to the original entrainment study at Scattergood Generating Station. This study as well as IRC (1981) were thoroughly reviewed by Energy Commission staff and consultants and, in their opinion, bias from sampling at the intake was not well accounted for (see Davis et al. 2002 cited for the Scattergood Generating Station).

7. Comment: Scattergood, Haynes and Harbor Generating Stations have recent impingement studies.

Response: The report states that impingement studies appear to be adequate for Haynes and Harbor Generating Stations. While Scattergood has continued to characterize impingement, the information reviewed for the report indicates this is only done during heat treatment. Thus, impingement data for Scattergood may be incomplete.

8. Comment: What is adverse? LADWP recommends that any discussion of what are, or attempt to define, what are adverse impacts be omitted.
Response: In the report, "adverse" is used as defined according to Webster's New World Dictionary (1984 edition), usage 2. = unfavorable. In the context of the effects of once-through cooling systems, it is used to assist in describing impacts that alter natural environments. It seems reasonable and useful to recognize that, regardless of the regulation being applied, once-through cooling systems have adverse impacts on natural environments. The objectives of good impact assessments are then to describe, as accurately as possible, what the adverse impacts are so that regulatory agencies can decide what to do about them.

9. Comment: LADWP believes that other contributors to the decline of fish populations should be listed.
Response: Disagree. The report is a review of studies used to assess once-through cooling impacts, not a review of all things that may be affecting the decline of fish populations.

10. Comment: Loss estimates such as those for South Bay are quoted and used without consideration of uncertainty.
Response: True, and given the space required to present uncertainties and the primary purpose of the report, these estimates were removed from the final report.

11. Comment: If the Scattergood Generating Station's Thermal Study was not reviewed, a judgment cannot be made as to its adequacy (Summary Table). Footnote to this table should reflect that the TWG was used under the CEC/CEQA review process.
Response: The statement about the Thermal Study in the draft report was incorrect and has been changed in the final report. Technical Working Groups are not necessarily related to CEQA - they are a procedure to help insure impact studies are done well regardless of the regulations the studies are being done for. For example, the Central Coast Regional Water Quality Control effectively used a TWG in conjunction with evaluating the NPDES permit for the Diablo Canyon Nuclear Power Plant (see Diablo Canyon Nuclear Power Plant and related literature in the Assessment Report).

12. Comment: If the author had reviewed all RWM studies, it is likely he would not have concluded that power plant impacts are largely unknown. The 1996 RWM study is not an appropriate representative study.

Response: Other RWMs for Scattergood were reviewed. See response to Comment 1.

13. Comment: While the Alamitos Generating Station discharges into the lower part of the San Gabriel River, when the plant was originally built the river was essentially dry and this historical baseline should be considered. The river was then dredged contributing to poor environmental conditions. It should not be concluded that generating station impacts to the river may be "extreme."

Response: Certainly the San Gabriel River has been subjected to numerous impacts, including large alterations in upstream flow prior to the construction of Alamitos and Haynes Generating Stations. Moreover, it is likely that dredging had substantial effects on the infauna (the Reish reports mentioned were not reviewed). The comment does not consider what effects Alamitos and Haynes Generating Stations might have on the river when it does flow (seasonally). At present, given the combined discharge of Alamitos and Haynes Generating Stations into this river with seasonal flows, it is reasonable to assume that the impacts may be extreme.

14. Comment: The southernmost discharge for the Haynes Generating Station is located approximately 1.8 miles from the river mouth (not 1 mile as stated in the report).

Response: Final report changed to 1.8 miles.

15. Comment: Preliminary surveys were done to evaluate the adequacy of pump sampling for entrainment studies at Haynes Generating Station (IRC 1981, Appendix G). EPA Guidelines (1977) indicated that pump sampling is acceptable providing it does not damage fragile organisms. Net sizes changed after the 7th survey, not "mid-way through the survey."

Response: The length and presentation of Appendix G made a thorough evaluation of procedures difficult. Given problems with pump sampling and related procedures in other studies, however, it is no longer used in entrainment studies. While the EPA may have felt that pump sampling was acceptable, the data suggest accuracy is questionable. Finally, it is not clear how changing mesh size even after the 7th survey (out of 64) may have affected the data. However, given these uncertainties, the report was changed to "-- the resulting entrainment estimates may be inaccurate."

16. Comment: The statement quoted in the report from WEI (1973) that thermal effects data at LA Harbor Generating Station "were not adequate to detect a discharge effect" could not be found in WEI (1973). Moreover, the 2004 RWM study reported that diversity and abundance was greater at the station nearest the plant effluent.

Response: The quote was from notes taken on WEI (1973). Since the original report could not be checked during revision, the quote was removed from the final report. The 2004 RWM report was unavailable during the original review.

The final report was modified to reflect the possibility that diversity and abundance are higher near the outfall.

17. Comment: The entrainment study done at Scattergood Generating Station did, contrary to Davis et al. (2002), correct for grazing losses, and entrainment data were reported as unrealistic only for species that were not abundant, not because of sampling difficulties.
Response: Davis et al. (2002) evaluated the data and techniques, and concluded the correction factors used were not well justified. Given this and other problems with the IRC entrainment study, it is possible that inappropriate sampling and correction contributed to the underestimates of abundances and the "unrealistic data."

18. Comment: LADWP is unaware of any velocity cap design standards.
Response: The statement in the draft report was incorrect, and removed from the final report.

19. Comment: Sampling impingement only during heat treatment produces accurate estimates of impingement because impingement is very low during normal operations.
Response: Without data or citation for this statement, it is difficult to evaluate. The statement is based on information from El Segundo. If it is true for El Segundo, would it necessarily be true for Scattergood?

20. Comment: In discussion of Scattergood Generating Station, the statement that offshore intake designs tend to maximize fish impingement relative to short, shoreline intakes lacks credibility. Offshore intakes are the technology of choice because they place the cooling water intake out of the zone of production (EPA). The CEC assigned an impingement reduction to SONGS due to the presence of an offshore intake structure.
Response: Contrary to EPA Guidelines, the number of fish that might enter an intake structure and ultimately be impinged is likely to be highly variable depending on the local environment. Moreover, shorelines are not necessarily any more productive (assuming this means high abundance of fishes that might be impinged) than offshore areas. The CCC (CEC was not involved in SONGS) may have assigned such a reduction to SONGS (information not reviewed), but SONGS still accounts for 97% of all the fish impinged by power plants in the Southern California Bight (see Cumulative Impacts Analyses in the recent draft impingement and entrainment report for Huntington Beach Generating Station cited in the Huntington Beach Generating Station section of the Assessment Report). Thus, the statement may be credible for a particular location, including Scattergood Generating Station.

Michael Krone, Pacific Gas and Electric Company (email August 31, 2003) - Comments 21-26.

21. Comment: Adverse Environmental Impact (AEI) is an important regulatory concept. References to the existence of AEI at specific plants should be deleted, or at least modified to indicate regulations for existing facilities are currently pending.
Response: See response to Comment 8.

22. Comment: It is important that this draft be reviewed and commented on by all parties, including plant owners, various Regional Board staffs, and other scientific peers.
Response: Drafts were provided to and comments solicited from all the groups mentioned plus other relevant California agencies.

23. Comment: The conclusion that 316(a) and (b) studies at Humboldt Bay Power Plant (and Pittsburg, Contra Costa and Potrero Power Plants) are fundamentally flawed and/or incomplete and out of date is inappropriate. At the time these studies were performed, the methods used were considered acceptable science.
Response: The original studies were fundamentally flawed. As an additional example, see the Background discussion for Potrero Power Plant, and Davis et al. 2002 in the literature cited for that plant. That the studies were acceptable to the agencies with regulatory responsibility does not necessarily mean the science was acceptable. Moreover, there have been numerous permit cycles since the original studies were done, permit cycles that allowed for better studies to be done as knowledge improved (see Introduction). Better studies have not been done except as a result of CEC review of prior studies at Potrero Power Plant.

24. Comments: Studies of the biological effects of the Humboldt Bay Power Plant were done in 1973. The report is available for review at our San Francisco headquarters.
Response: As stated in the Assessment Report, the 1973 report was not available at the NCRWQCB. However, the more recent 1983 PG&E report on thermal effects was available and did not contain any biological information. Since the thermal plume has changed since 1973 as a result the shut-down of the nuclear generating unit, it is reasonable to assume that biological impacts have changed since 1973, and new thermal effects studies are needed.

25. Comment: Sections related to the Coastal Commission and mitigation associated with San Onofre Nuclear Generating Station should be deleted since these are not relevant to assessment requirements under the Clean Water Act.
Response: The Assessment report is not about assessment requirements under the Clean Water Act (see Introduction). The additional information on San Onofre Nuclear Generating Station is included as impact studies and mitigation

there were the first to be required and reviewed by other than Regional Water Quality Control Boards, and are representative of recent approaches to determining adverse impacts and what to do about them.

26. Comment: The recommendation that the evaluation of San Onofre Nuclear Generating Station (SONGS) that cost $50 million dollars be used as a model for evaluation and mitigation of power plants should be deleted. The requirements are unique to the Coastal Commission and do not reflect the requirement of Clean Water Act that balance technical and economic feasibility.

Response: Models and approaches to impact analyses developed during the Coastal Commission evaluation have been applied, with modification, in subsequent impact evaluations at other power plants in California (e.g., see reviews for Diablo Canyon Nuclear Power Plant and Moss Landing Power Plant). These models and approaches provide much more accurate and comprehensive analyses of impacts, allow for estimation of impacts to other than fished species, and allow for appropriate mitigation (see Introduction). The cost of the SONGS evaluation was unique to SONGS - there is no implication that this would be the cost at all power plants, and costs of evaluations of other power plants done since SONGS have been very much less. The comment provides no evidence that the Coastal Commission did not, as for the Clean Water Act, "balance technical and economic feasibility."

Guy Chammas, Senior Environmental Specialist, and Steven J. Bauman, Senior Environmental Engineer, Mirant California LLC (email comments August, 2003 and letter with comments May 11, 2005) - Comments 27- 31.

27. Comment: The mesh size used in the 1993 thermal study at the Contra Costa Power Plant was consistent with that used by CDFG in the delta to avoid clogging.

Response: Report revised removing suggestion that this net size may be inappropriate.

28. Comment: Mesh size for the entrainment study at Contra Costa Power Plant was used for the same reasons as in comment 27. The discharge is an appropriate location for documenting take of ESA species. Agree that in the future, entrainment sampling should be conducted by towing obliquely through the water column in front of the intakes and at source water stations to allow for the calculation of proportional entrainment.

Response: Report revised as per response to comment 27 concerning mesh size at both Contra Costa and Pittsburg Power Plants. The discharge may be an appropriate location for sampling ESA species but, as indicated in the last part of the comment, a more comprehensive and accurate assessment of entrainment impacts is needed, and requires water column sampling.

29. Comment: The draft report found that thermal effects studies at Contra Costa Power Plant (and Pittsburg Power Plant) were inadequate; however, the report

did not acknowledge the full range of thermal effects study elements to determine the distribution of fishes in relation to the thermal plume. Studies were designed to study species of special interest, not just striped bass, and 500 micron mesh was consistent with mesh sizes used in the Delta by CDFG and other agencies.

Response: Many of the thermal effects study elements related to fishes were reviewed, and it was not clear how relevant the elements were to an accurate assessment of thermal impacts. The Assessment Report was modified to reflect that fishes other than striped bass were examined, and that 500 micron mesh nets are consistent with those used by other agencies.

30. Comment: Do not agree that the 1978-80 entrainment methods at Contra Costa Power Plant (or Pittsburg Power Plant) were flawed as portrayed in the draft report. Because biofouling is not a problem in the Delta, the cropping problem does not occur.

Response: Biofouling was not mentioned as a problem for these entrainment methods, but other problems were, and these were the basis of the conclusion that the methods were flawed (see Contra Costa and Pittsburg Power Plant sections of Assessment Report).

31. Comment: The CEC did not ask for a new 316(a) study for Potrero Power Plant, and a new entrainment study for this power plant was submitted to the SFBRWQCB in March 2005.

Response: True. The final report was revised accordingly.

Kerry Whelan, Principal, Water & Wastewater, Reliant Energy (email, April, 2005) - Comments 32 - 33.

32. Comment: The report concludes that past and most current IM&E studies are "inadequate." It should be recognized that data may have more or less scientific relevance depending on the intended use. Older data may be invaluable for indicating trends, for example. The report would benefit from elaboration on the metrics upon which these judgments (of adequacy) are made. From a permittee's perspective, adequacy is a function of whether the action is determined by the appropriate regulatory authority as fulfilling requirements of a rule.

Response: Current, comprehensive thermal, impingement and entrainment studies (for Diablo Canyon and San Onofre Nuclear Generating Stations, Morro Bay, Moss Landing, South Bay and Potrero Power Plants, and Huntington Beach Generating Station) are indicated as adequate or accurate in the Assessment Report. It is true that older data may indicate interesting trends, but they do not accurately describe entrainment impacts (or, in many cases, thermal and impingement impacts - see reviews for individual power plants). Since the fundamental purpose of these studies was to accurately describe these impacts, the studies are inadequate. The metrics and, more importantly, the study designs, analyses and interpretation of the results used to determine adequacy are generally described in the Introduction, with details provided in the individual reviews. This "adequacy" is quite different from the permittee's perspective; it is based on the quality of the scientific evidence for impacts (or lack thereof).

33. Comment: Impingement assessments at the Mandalay plant began again in May 2001 and has continued on a bi-monthly basis to the present. Impingement sampling at the Ormond Beach plant has been conducted on approximately a monthly basis at the site from 1990 to the present.
Response: The Assessment Report was revised to include this information.

Tim E. Hemig, Director, Regional Environmental Services, West Coast Power LLC (letter April 11, 2005) - Comments 34 - 42.

34. Comment: The usefulness of the Draft Report as a tool for planning and assessing studies of power plant intake and discharge effects is very limited. The report only includes one-sided arguments of why existing information is inadequate. All scientific information is limited, but this should no preclude its use in answering certain questions as part of an overall data set to enhance knowledge and understanding. The Draft Report also draws conclusions regarding certain studies that are not supported by the facts and/or makes misstatements about certain facts. In contrast to the information presented in the report, there are a number of power plants that have rich archives of historical records and documentation of cooling water impact analyses.
Response: The Assessment report, as well as reviews of existing information done prior to new assessments at Diablo Canyon Nuclear Power Plant, Moss Landing, Morro Bay and Potrero Power Plants, and Huntington Beach Generating Station required by the CCRWQCB or the Energy Commission, consistently found that existing information, especially for entrainment impacts, was not sufficient to accurately determine impacts. The same conclusion was reached by Energy Commission staff and consultants for El Segundo Generating Station (see literature cited for these various power plants in the Assessment report). There is, therefore, considerable scientific evidence that existing information is commonly "inadequate." Are there other sides to the argument? If so, they should be stated. Certainly if the quality of any existing information is sufficient to answer "certain questions," the information should be used. Unless these "certain questions" are explicitly stated, however, it is impossible to know how relevant the answers to them would be to determining thermal, impingement and entrainment impacts. While there may be "rich archives," it does not follow that the information in the archives is necessarily useful to determining impacts. It was these archives that were reviewed in the Assessment Report. See also responses to comments 4., 23 and 32.

35. Comment: The report should begin with a statement of the regulatory setting.
Response: The assessment report is not about regulations or regulatory settings. See Introduction.

36. Comment: The Draft Report implies that it is not possible to do an adequate study unless there is independent oversight similar to the workgroups used on the DCPP, MLPP, MBPP, etc. All of the studies we are aware of had some level of agency involvement, usually resource agencies such as CDFG and National Marine Fisheries Service. Most studies that are qualified as "inadequate" have, in fact, been fully accepted and approved by the primary agencies with jurisdictional authority over the Section 316(a) and 316(b) regulations. The original studies at South Bay Power Plant and the Encina Power Station were both excellent studies and did not involve independent oversight to our knowledge although they did have resource agency involvement.

Response: That is not the implication. However, it is clear from reading and critically evaluating the methods, analyses and interpretation of the results of prior versus recent studies that independent oversight results in more adequate studies (see also Introduction). Resource agencies (and Regional Water Quality Control Boards) commonly do not have the time or expertise to carefully and critically review studies, so their involvement does not necessarily insure studies will be done adequately. The original study at South Bay Power Plant is acknowledged in the Assessment report as being "reasonably well done." Relative to more recent study designs (see Standards for Evaluation in Introduction, and review of Encina Power Plant), the original study at the Encina Power Station was not considered "excellent."

37. Comment: The conclusion that the 1979-80 entrainment study at Encina Power Station was "fundamentally flawed" and "no re-analyses of the data can give an accurate estimate of current entrainment impacts" is inaccurate. The studies were thoughtfully designed and well executed for their time and now, and used the same ETM model that the Draft Report also cites as critical to the success of more recent studies.

Response: The reviews for the Draft Report were done prior to the initiation of the new entrainment study at this power plant. It was not clear from the reports that were available how ETM was used, and sampling designs suggested even if it were used, the results may be inaccurate. That a new study is being done further indicates there were problems with past studies. However, the suggested new analyses may provide new insights into the past studies. In anticipation of the rigorous retrospective that apparently will be part of the new entrainment study, conclusions about ETM, flaws and re-analyses were removed from the Assessment report.

38. Comment: The Draft Report indicates that there is re-circulation of heated water back into the lagoon at Encina Power Plant. Results from various studies have shown that there is little if any such re-circulation.

Response: The studies reviewed for the Assessment report indicated as stated that "some heated water enters the lagoon with incoming tides." This may be "little."

39. Comment: It is concluded that thermal effects studies done at El Segundo Generating Station were adequate. This conclusion is inconsistent with conclusions regarding the thermal studies at other facilities, such as Ormond Beach, which were similar in design to the studies at ESGS.

Response: Similar is not the same; studies and discharge environments differ. As suggested in the Assessment report, Ormond Beach may be adequate depending on what is shown by integration and evaluation of the information from various reports. ("further biological sampling may be necessary," and "impacts to the sandy beach may be minimal.")

40. Comment: Impingement has been measured regularly at El Segundo Generating Station since the 1970s.

Response: The statement about lack of impingement data in the Assessment report was incorrect and has been removed.

41. Comment: It is important to point out that a complete 316(b) study was conducted for El Segundo Generating Station in the early 1980s. While the entrainment data was actually collected at the Ormond Beach Generating Station, it was based on a careful assessment and demonstration (reported in 1979) to characterize facilities of similar physical and biological similarities. The LARWQCB reviewed and approved the representative studies approach. The draft report makes no reference to the work done to make this demonstration and appears to not have been aware of its existence. The Draft report does not include any of these facts regarding the original 316(b) study.

Response: The 1979 assessment and demonstration report was carefully reviewed, and comments on in the Ormond Beach Generating Station section of the Assessment report. The reader is directed to this review in the El Segundo Generating Station section of the report, and in the sections for all other power plants that were included in this "representative studies" 316(b) approach. As the discussion in the Ormond Beach Generating Station section of the Assessment report points out, there were numerous problems with the 1979 assessment and demonstration that make the accuracy of the entrainment estimates at all power plants for which it was used unknown. See also review by Davis et al. (2002) cited in the section on the El Segundo Generating Station. See response to comment 26. regarding agency review and approval.

42. Comment: The statement that "-- the volume of cooling water used (for the repowering project at the El Segundo Generating Station) will likely increase impingement relative to recent levels" is misleading since it implies that repowering will result in increased flow rates.

Response: The statement was modified for clarity.

<u>Agency Comments</u>

Tom Luster, California Coastal Commission (letter March 21, 2005) - Comments 43 - 45.

43. Comment: Suggests the inclusion of discussions on (1) applicability of different statutes and regulations, (2) guidance for future studies, (3) historical studies that include a description of changes in California's marine environment, and (4) differences between older and newer studies for determining mitigation. These may go beyond the scope of the report, but they could be used to guide follow-up Energy Commission efforts to further address the effects of once-through cooling.

Response: These are important topics but are beyond the scope of the Assessment Report. They are all being addressed in follow-up efforts by the Energy Commission.

44. Comment: The final version of the report should update the description of the El Segundo and Huntington Beach Generating Stations to reflect recent Energy Commission decisions and the status of more recent studies.

Response: The final version of the report will be so updated.

45. Comment: It would be helpful for the formats of the Moss Landing and Morro Bay descriptions to match the formats for other power plants.

Response: These are the only power plants for which recent and thorough impact analyses have been done, and they also have few ongoing studies or unresolved impact issues. Therefore, a different format was used in the interest of saving space and avoiding repetition. The details of impact assessment for these power plants can be found in the literature cited for them.

Other Comments

Craig Shuman, Heal the Bay (letter March 18, 2005) - Comments 46 - 49.

46. Comment: Although it may be outside the scope of this study, the report lacks a succinct section for conclusions and more importantly for recommendations.

Response: The results of the review are summarized in the Introduction and the Summary Table. The primary conclusions are made on a power plant-by-power plant basis as they are site specific. Recommendations that stem from this report and other work by the Energy Commission are being made in a separate document.

47. Comment: Further detailed explanation regarding the inadequacies of "surrogate" studies would be beneficial.

Response: Surrogate studies are not necessarily inadequate. Problems with the 1980 surrogate study done for some power plants in the Southern California Bight are discussed in the Ormond Beach Generating Station section of the report. Surrogate entrainment studies could be adequate if the species composition, abundance and size (fish larvae) of the organisms where shown to be very similar among intakes and in the relevant source waters. How similar remains to be determined, and would probably be determined on a location-by-location basis. See also responses to comments 5 and 41.

48. Comment: Is there a way to introduce the idea of historical baseline and to expand on the notion that current sampling may not account for decreases in populations resulting from prior impacts?
Response: The idea is not within the scope of this report, but will be considered in other documents being prepared by the Energy Commission. Impact assessments for once-through cooling systems have not yet been designed that can account for decreases due to prior impacts. Moreover, prior impacts often include others in addition to those from the cooling system, making it difficult if not impossible to separate the impacts of the cooling system alone. Clearly an important problem that needs further consideration.

49. Comment: Is there any empirical evidence to support the assumption that ecological impacts are unlikely for planktonic inverts and phytoplankton?
Response: Since impingement and entrainment studies focus on fish and sample with devices that do not capture smaller organisms, impact reports have little information on phytoplankton, and zooplankton other than fish larvae. A limited review of the scientific literature suggests there is not much of information on these other, smaller organisms. They are difficult to count, and their survivorship is difficult to follow versus individuals that were not entrained. Some studies suggest elevated temperatures may increase phytoplankton productivity. Recent work by N. Welschmeyer (Moss Landing Marine Laboratoris, pers. comm.) indicates that bacterial growth rates increase and phytoplankton growth rates decrease a result of passing through the Moss Landing Power Plant. The former is interesting as it might help explain elevated bacterial concentrations on the shore at Huntington Beach? It does seem reasonable to assume that because of their very high reproductive rates and concentrations, entrainment has only small effects on small, adult planktonic forms. It would be useful, however, to thoroughly review the literature on this topic.

50. Comment: Various suggestions and editorial comments made in a list of specific comments.
Response: These were considered, and incorporated as deemed appropriate.

John Steinbeck, Tenera Environmental (e-mail March 25, 2005) - Comments 51 - 56.

51. Comment: Various editorial suggestions and specific comments made to improve the report.
Response: The suggestions were useful, and incorporated where deemed appropriate.

52. Comment: There is an implication that it isn't possible to do an adequate study unless there is independent oversight. All studies I am aware of have some level of oversight from agencies such as CDFG. The original studies from the early 1980s at the South Bay Power Plant and Encina Power Station were both excellent but had no independent oversight.
Response: See responses to comments 36 and 37.

53. Comment: There may be flaws in the designs of some of these past studies, but the information is still valuable especially in designing or analyzing the data for a new study.
Response: Agreed. The question investigated, however, was how well do the past studies assess impacts.

54. Comment: A 500 micron mesh size is adequate for most ichthyoplankton studies and is the standard mesh used in CalCOFI sampling.
Response: Agreed, but smaller mesh sizes provide more information on fish eggs and the invertebrate larvae. However, since almost entrainment impact assessments focus on fish, the Assessment report was revised to reflect that 500 micron mesh is currently considered acceptable. This may change if impact detection standards are raised to include more organisms. Given observations of extrusion, etc. with this mesh size, however, it is reasonable to question how changing net sizes during a study affects the detection of impacts on fishes.

55. Comment: Disagree with the conclusion that the 1980 and 1997 316(b) reports for the Encina Power Plant are "fundamentally flawed."
Response: See response to comment 37.

56. Comment: Lower velocity at shoreline intakes is due to the increased surface area not their 'short' length (Scattergood Generating Station review).
Response: This statement was incorrect and is modified in the final report.

Shane Beck, MBC Applied Environmental Sciences (email March, 2005) - Comments 57 - 59.

57. Comment: The description of the 316(b) studies relates to how the results would be interpreted by the CEC, not compliance with the actual rule.
Response: See response to comment 35.

58. Comment: I think many 316(a) and (b) studies in southern California were adequate to determine potential physical and biological effects. Both nets and pumps have foibles, and I think both can be used to sample entrainment.
Response: Disagree with first statement and, for the reasons given in the Assessment report, would argue that while they had the "potential," it is not known how well the potential was achieved. Agree with the second statement, but based on the information reviewed, the foibles with pumps have never been

adequately characterized such that the results from using them can be considered accurate.

59. Comment: Comment: Various editorial suggestions and specific comments made to improve the report.

Response: The suggestions were useful, and incorporated where deemed appropriate.

APPENDIX C: SUMMARY OF ASSUMPTIONS, METHODS, AND ANALYSES USED IN RECENT STUDIES TO ASSESS THE IMPACTS OF POWER PLANTS THAT USE SEAWATER FOR ONCE-THROUGH COOLING, AND CONCEPTUAL AND RESEARCH APPROACHES TO IMPROVE ASSESSMENT OF ENTRAINMENT AND CUMULATIVE IMPACTS

Summary of Assumptions, Methods, and Analyses Used in Recent Studies to Assess the Impacts of Power Plants that Use Seawater for Once-Through Cooling, and Conceptual and Research Approaches to Improve Assessment of Entrainment and Cumulative Impacts

Entrainment Impacts

The estimation of impacts from entrainment is complex and technical, requiring comprehensive field sampling and laboratory analyses, life history information on the species entrained, and a variety of analytical procedures. Only an overview is provided below; a detailed review is being prepared for the Energy Commission (Steinbeck et al. in prep.).

Sampling Design

Entrainment studies begin with a literature review and preliminary sampling to define the species whose larvae are entrained and the water body from which they likely come. Available methods and costs currently constrain the species that can be directly assessed to those with large larvae that can be identified - fishes, and invertebrates such as crabs. Larvae of other invertebrates are impacted but difficult to sample due to their small size, and often difficult to identify to species. This may change as estimates using molecular techniques are better developed and become less expensive. Adults and other stages of small planktonic invertebrates (e.g., copepods) and phytoplankton (e.g., diatoms) are generally not sampled due to their small size and the assumption that their large population sizes and rapid growth and reproduction make ecologically important impacts unlikely.

The water in front of the intake and at appropriate locations away from the intake is sampled for at least a year using plankton nets with a mesh size of or close to 300 microns. The depth and temporal scale of sampling depends on temporal variability in larval behavior and abundance. The goal is to provide an accurate estimate of the species composition, number, and size of larvae available in the water that are potentially subject to entrainment (samples from water away from the intake), and the species composition, number and size of larvae actually entrained (samples from water very near the intake). If the intake is in open coastal waters (not bays or estuaries), coastal circulation data and models of water movement are used to assess water circulation in the vicinity of the power plant. This information is used to help determine the area of coastal waters that contain the larvae that are likely to be entrained. This area varies among species depending on how much time their larvae spend in the water and, thus, are vulnerable to entrainment. Most of the larvae entrained by a power plants in a bay or estuary are produced in the bay or estuary. In these environments sampling and/or prior knowledge is used to define an area from which the larvae entrained are likely to come, and this source water area is used for all species.

Adult Equivalent Loss (AEL) and Fecundity Hindcasting (FH) Impact Analyses

The number of larvae (by species) killed by entrainment is estimated by scaling the larval abundances/volume sampled in front of the intake to the volume of water entrained by the power plant in a year. Larval mortality from entrainment is assumed to be 100 percent for reasons discussed below. This mortality, combined with the size of the larvae and knowledge of natural larval survivorship (Figure 1) is then used to determine how many adult equivalents (Adult Equivalent Loss or AEL) or the fecundity (reproductive output) of how many adult females (Fecundity Hindcasting or FH) is lost because of entrainment mortality. Combining AEL from entrainment with adult losses from impingement provides an overall estimate of adult mortality caused by the cooling system.

Proportional Mortality and Habitat Production Foregone Impact Analyses

Sampling larvae in the water away from the intake, so called “source water sampling,” allows estimation of the proportion of larvae in the water that could be entrained that are actually entrained and killed, called Proportional Mortality (PM). This indicates the impacts to the larvae themselves. PM and knowledge of the area of coastal or estuarine water that contains the larvae that can be entrained indicate the overall extent of larval loss. This can be reduced to the area equivalent of 100 percent mortality. For example, if the average PM for all species is 10 percent and the average area containing the entrained larvae is 1000 acres, the area equivalent to 100 percent loss is 100 acres. This area of 100 percent loss has been called “Habitat Production Foregone” (HPF; Strange et al. 2004; examples from recent impact assessments in Table 1). If one assumes that PMs and source waters for the larvae that can be assessed are similar to those of larvae that are not assessed, then HPF is a more comprehensive and realistic estimate of entrainment impacts than only AEL or FH for fishes. It is also a useful metric for determining possible mitigation for these impacts (Strange et al. 2004).

Assumption of 100 percent Mortality

It has been argued that many organisms survive entrainment and, therefore, entrainment impact assessment should be based on determinations of the actual number killed, not the number entrained (review in EPRI 2000). A partial review of entrainment survival studies done by power plants in California revealed that such studies have shown, using techniques ranging from chemical analyses to determine metabolic activity to survivorship of individuals collected from the discharge (usually determined over a few days in laboratory tanks) that not all organisms are completely dead when they exit the discharge. However, there are no studies of the subsequent survivorship and reproduction of these individuals in nature versus the survivorship and fecundity of similar individuals that are not entrained. Moreover, the mortality estimates from traditional studies are generally high. Given this uncertainty and the lack of evidence indicating otherwise, 100 percent mortality has been assumed in recent entrainment studies in California (e.g., Tenera 2000b).

Insert Figure 1

Assumption of No Compensation

There is debate over whether or not the mortality of eggs, larvae and adults caused by entrainment and impingement results in the reduction of the size of adult populations. Populations may “compensate” for the loss of eggs and young by, for example, increased reproduction (review in Rose et al. 2001). If such compensation occurred in populations impacted by entrainment and impingement, then the impacts on adult populations would be reduced. While compensation should occur in theory, it has been difficult to demonstrate in populations in the field (Rose et al. 2001), and Nisbet et al. (1996) conclude, “Optimistic outcomes (of compensation) all appear to demand mechanisms which have not been proved in *any* marine fish *anywhere*.” The USEPA (2004) reviewed compensation as it might apply to impingement and entrainment impacts, and concluded that the potential for compensation may, in conjunction with other impacts such as fishing, be compromised by once-through cooling systems. It may be that, given multiple impacts, “depensation,” the opposite of compensation, may occur, greatly reducing the ability of populations to recover after their abundance has been reduced. Moreover, the recruitment of adults in estuarine and coastal marine fish and invertebrate populations is well know to be highly variable among years, and this variability can result from natural variation in larval survival. In contrast, most once-through cooling systems operate with little variation; they do not “compensate” by reducing mortality when natural larval survival may be low. High larval and spore abundances may also be critical to long term population persistence by increasing the chances of successful dispersal to suitable habitat (e.g., Reed et al. 1988). Finally, live larvae and other small life stages are no doubt fed upon by other species, and these sources of food are reduced by entrainment. For these reasons, the USEPA and the Energy Commission currently consider that compensation does not reduce impacts from entrainment and impingement on adult populations.

Need to Better Determine Source Water (Withdrawal Zone)

In much the same way that one can map the area impacted by the thermal discharge, the area impacted by entrainment needs to be mapped if entrainment impacts are to be reliably estimated. However, the question here is not where water goes, but where it came from – a more difficult problem to observe directly with field observations. Ultimately, probability maps should be available for each cooling water intake and for each of a variety of common oceanographic conditions. These probability maps can be developed through a combination of field observations and computer modeling. Areas from which there is a high probability of entrainment may be characterized by a limited number of events but each with very high probability, or by persistent entrainment at a lower level.

The entrainment impact of withdrawing water, however, depends on the concentration of plankton or weakly swimming organisms of concern that are found within this withdrawal zone. In evaluating each power plant, boat-based surveys of marine organisms at risk should be repeated under a variety of oceanographic conditions to allow assessment of whether distributions change little in time (in which case the entrainment can be estimated by multiplying withdrawal volume by plankton concentration) or whether distributions change strongly with changes in the withdrawal zone (in which case the entrainment must be estimated by overlaying maps of plankton concentration and withdrawal zone for each of the most common oceanographic conditions identified). This latter scenario of correlated changes in distributions and flow patterns is very likely to occur and can result in entrainment impacts orders of magnitude greater or lesser than that obtained by assuming constant distributions.

Finally, the withdrawal zone may be continuously replenished with organisms that were initially beyond the zone as a result of a diffusive flux of organisms into the withdrawal zone. This diffusive flux can result from small-scale flow structures or swimming behavior and will be directed into this zone where plankton concentrations are being reduced by entrainment. To properly assess entrainment levels, this flux also needs to be assessed.

Impingement Impacts

Impingement sampling methods are straightforward: organisms caught on the power plant intake screens are identified and counted. Studies are designed to produce an accurate estimate of all fishes and invertebrates impinged during a typical year, and repeated, especially if source populations change. The impacts are expressed as the number of individuals of each species killed.

Thermal Impacts

The temperature of the natural waters where the power plant discharges (receiving waters) are sampled under the full range of operating and environmental conditions to produce a 3-dimensional (horizontal and vertical) map of thermal plume distribution. This map shows the probability of a particular elevation in temperature above ambient (delta T; often in 2 deg. F increments from the highest down to 2 deg. F) occurring within the plume and on any substrate the plume contacts. The map is used to define areas of varying plume contact with the substrate.

To estimate effects on benthic (bottom dwelling) organisms, organisms are sampled along gradients of temperature caused by plume contact and the data analyzed for changes related to changes in temperature. Sampling designs for each benthic habitat type are analyzed for statistical power to detect change in the species sampled, and modified depending on the level of detection desired. Since gradient designs can be confounded by variables other than temperature (e.g., gradients in grain size), sampling designs and analyses strive to separate the effects of these other variables. Laboratory studies may be necessary to better determine if temperature is likely to be the most important cause of a change. Unless the natural receiving waters are confined such that plume dissipation is restricted (i.e., most often a bay or estuary), thermal effects on organisms in the water column are assumed to be minimal and normally not sampled for possible impacts.

The effects or impacts are expressed as the area over which impacts occur and changes in populations caused by the discharge in this area (e.g., Tenera 1977).

Cumulative Impacts

As concluded in a recent review by MBC/Tenera (2005), there are few recent examples of cumulative impact analyses for coastal power plants using once-through cooling. Of the two examples given, one was based on cumulative losses relative to fisheries and, therefore, only considered those species entrained that were fished. The other, examining cumulative effects on Atlantic menhaden, another fished species, found these difficult to determine because of lack of data on impingement and entrainment from East Coast power plants (MBC/Tenera 2005).

While it is unlikely that a combination of two power plants will entrain more than the sum of the two affects individually, the proximity and volume of seawater intakes pose the question of how much of the total population is entrained by power plant intakes. It is not sufficient to assess the proportional entrainment of a single intake when there are multiple intakes distributed throughout the region. For example, if each intake entrains 10 percent of larvae in local waters and power plant intakes are found throughout the spatial extent of a given species, then one can expect that 10 percent of the entire larval population is entrained. These meta-population impacts need to be quantified and assessed in the light of cumulative impacts from other anthropogenic sources of mortality. When does the cumulative anthropogenic mortality exceed that sustainable by the population – when do we cross a threshold (a tipping point)? A second meta-population concern, considered critical in discussion of marine protected areas, is the need for "stepping stones" for a meta-population distributed over fragmented habitat. If larvae can only disperse from one habitat island to the next (e.g., rocky outcrop), what happens when one of these stepping stones is subject to high levels of larval mortality? Protocols are needed to address the importance of local entrainment impacts on the population as a whole.

Needed Research

The cumulative effects estimates made to date for California coastal power plants (see text) are based on very simplistic assumptions about larval distribution and nearshore circulation. Rather than being uniformly distributed in the water, larvae are likely to be "patchy;" aggregated at smaller spatial scales due to behavior and small scale ocean mixing. Better cumulative impact models need to ascertain the fate of these patches and the time they are exposed to power plant intakes. This will be somewhat dependent on changes in the larval population as it drifts (e.g., mortality, growth to more mature stages), but will be more dependent on the physical oceanographic context that determines the movement of the patches. If, for example, the patch drifts northwestward along the coast of southern California, how many times will it encounter power plants and how much of its larval mass will be removed? This is a simple calculation assuming constant alongshore drift, but tidal movement needs to be added to make it more realistic. As patches flow past a plant tides may actually move them back and forth several times, resulting in even greater intake entrainment. In addition, knowledge of the region's physical oceanography indicates that although the mean flow is northwestward, this can be reversed for periods of at least several days, which is about the same time scale as the patch's traversal of Santa Monica Bay. During spring upwelling, currents can be southeastward for even longer periods of time. This variability needs to be considered. An additional complication to the simple model of alongshore advection of a patch past intake pipes is the question of whether the patch migrates on and offshore with any predictable pattern. This will also affect its exposure to nearshore power plants.

Key to assessing the importance of spatial and temporal variability to estimating cumulative entrainment is the development of an initial set of simple, analytical model solutions addressing the outcome of a variety of situations. This would involve generating a hypothetical set of patch scales and running them along the coastline with a set of idealized velocity vectors representing know low-frequency and tidal currents. These hypothetical quantities would not be pulled from thin air, but would be based on a thorough literature search of the physical and biological oceanographic literature of the region where cumulative impacts are to be assessed in order to estimate the likely range of these velocity vectors. A similar modeling and literature search technique could also be used initially to examine temporal variability of larval abundance, facilitated by information from recent entrainment studies. Some information on larval patchiness might also be obtained from a literature survey, but the best assessment would require shipboard sampling.

Field sampling should begin parallel with modeling to obtain a good time series. This might be in conjunction with an existing entrainment study that includes a sampling grid for the source water (e.g., as was done for the study at Diablo Canyon Power Plant; Tenera 2000a), with added sampling to better estimate larval patch sizes. Sampling would be done frequently enough to determine temporal variability at the time scales known to be important to particular larval populations. Physical oceanographic sampling would include a few fixed current meter moorings to provide a good time series of shelf currents. These should include depths and locations that give a true indication of the advective scales important to larval distribution. Similar studies over small spatial scales would provide more accurate models for cumulative impacts in more enclosed regions such as estuaries.

APPENDIX D: RESEARCH RECOMMENDATIONS FROM THE ENERGY COMMISSION PIER WISER WORKSHOP ON APRIL 13, 2005

Research Recommendations from the Energy Commission PIER WISER Workshop on April 13, 2005

I. Develop long terms datasets for understanding coastal power plant ecological effects
   A. Determine if these sets may already exist in some form for some areas
   B. Determine the limitations of these existing sets
   C. Design a study in one area of CA as a pilot area
   D. Monitor this area for long term (possibly add other areas later)
      Points to consider in developing a study:
      1. What evidence would we need to determine there were power plant effects?
      2. How would you monitor so that you could detect effects?
      3. Where would you expect the effects to show up (near the plant or much farther away?)
      4. What is the “signature” of a power plant effect and how do you tease that apart from other anthropogenic and environmental effects?
      5. What do these effects look like over the long term (cumulative effects over time)?

II. Which are the “best” metrics to use to measure an impact? What data do we need in order to determine which is “best”?
   A. Life history data, especially natural mortality coefficients and size-length or age-length relationships, are needed.
      Points to consider in developing a study:
      1. Are there existing datasets out there that are useful? Locate these?
      2. Can we modify, through collaborative effort, on-going studies (by other groups or agencies) so that they could provide the data needed?
   B. These data translate to AEL, ETM, and FH, better data means better estimates
      1. Is there a best model?
      2. Can we choose one so that there is a common currency used so that plants can be compared directly and cumulative effects determined easily (consider standardizing use of Proportional Mortality (PM)?
      3. Oceanography - what is the area of effect, individual and cumulative?
   C. Hydrodynamic modeling needed
   D. Estimates of larval duration or retention times needed
   E. Are there existing monitoring stations that we can use to gather oceanographic information (IOS systems)?

IV. How can we better ID/enumerate species that are entrained (or otherwise impacted)?
   A. How can we ID/enumerate species of special status?
   B. Are there techniques for species ID/enumeration that are cheaper, better, faster?
   C. Can we choose "indicator" species each of which biologically represents some portion of the other species being caught? All of the indicator species taken together should/could represent everything being entrained? Can we monitor these as proxies for all the species, thereby improving our understanding of power plant effects, but at a reduced cost.

V. Survey of CA energy consumers (need economist)
   A. Are they willing to pay X more on their bills to somehow offset entrainment losses?
   B. Are they willing to do this without knowing the $ cost to themselves?
   C. Are they willing to do this without knowing the "cost" of lost organisms?
   D. How do you determine the cost or value of organisms (to the energy consumer)?
      1. What is the value of knowing the system is intact?
      2. What percent loss is acceptable to the general consumer?

VI. What is the monetary benefit to CA power plants of once-through cooling?

VII. What are the benefits (percent reduction in entrainment) of technology?
   A. Variable Speed Pumps or Variable Frequency Drives
      1. When would a plant ideally use the different speeds (if they can choose)?
         a. Requires a knowledge of what organisms are in the water, when (time of day and year), and doing what (i.e., spawning)
      2. Will flow reduction have a benefit?
         a. Can organisms actually escape intake if flow slower?
         b. Is there a trade off of increased impingement with decreased entrainment?
         c. How important/detrimental is the increased thermal output that results?
   B. Real field data needed for Gunderboom
      1. Can you leave this on for extended periods of time?
      2. How much crossflow do you need to keep it clear of sediment?
      3. Bio-fouling
   C. Fine mesh screen technology
      1. Can it really be implemented by the plants (field data needed)?
      2. What about fish behavior and attraction to the screens (Delta studies)?
   D. Other viable reduction techniques?
      1. Sound barriers

2. Bubble screens
3. Fish returns (effective, but can we make these less costly)?
4. Others?

VIII. Monitoring mitigation efforts

A. What are the criteria for success?

Points to consider in developing a study:

1. What variables do you measure?
2. Where do you measure (in and outside of affected area)?
3. Over what time frame?
4. What is “success”

Are there good indicator species that can be monitored to reduce the cost of overall monitoring effort?

APPENDIX E: ECONOMIC COSTS OF ONCE-THROUGH COOLING IMPACTS BY ROBERT UNSWORTH INDUSTRIAL ECONOMICS

Economic Cost of Once-Through Cooling Impacts

As discussed in previous sections, the use of ocean water for cooling by electric generating facilities can lead to ecological impacts. The purpose of this section is to discuss available methods for assigning economic values to these impacts, as well as some issues that arise in the application of these methods. While placing dollar values on changes in the natural environment can be controversial, economic analyses, when carefully developed and clearly presented, can provide important information for the public, corporate decision-makers, public policymakers, and regulators (e.g., to help the public understand the relative magnitude of economic benefits relative to the costs of facility modifications required to achieve such benefits).

Conclusions

This section highlights several important issues in the application of economics to value the environmental impacts of once-through cooling. These include:

- To-date, attempts to measure the public's total willingness to pay to reduce the environmental impacts associated with once-through cooling have been limited. Past studies have generally considered the most easily quantified and monetized impact categories, such as reductions in commercial and recreational fish harvest associated with impingement and entrainment. In addition, the standards of economics have not been consistently and universally applied in these analyses. As a result, little information is available on the public's true value for actions or policies that reduce these impacts.

- It is often suggested that equivalency-based approaches can provide a measure of the public's willingness to pay for reducing the environmental impacts associated with once-though cooling. These methods, however, generally can only provide measures of the *cost* of off-setting these impacts. While regulators and the regulated community have successfully used equivalency-based approaches to reach agreements on the scale of actions to offset the impacts of once-through cooling, these agreements in and of themselves do not provide measures of the public's willingness to pay to avoid the effects of once-through cooling. As more is learned about the biological impacts of once-through cooling, the scale of the required off-sets could increase, raising further questions regarding whether the cost of these efforts exceeds the public's willingness to pay (i.e., the costs of reducing the impacts of once-through cooling could exceed the benefits).

- Many of the analyses conducted to-date have not explicitly addressed the baseline conditions of impacted resources (e.g., the condition of affected resources in the absence of the impact of once-through cooling). Variations in baseline conditions an especially important consideration in the context of transferring economic values for reductions in once-through cooling from one site to another, and could introduce significant error to these analyses.

- Most of the past assessments of the environmental impact of once-through cooling have provided too little information on the sensitivity of the results to reasonable variations in the underlying assumptions. In many cases, the range of uncertainty is quite large. These include uncertainties associated with the underlying bio-physical science, as well as in the economic and cost analyses. Without sufficient presentation of uncertainties, stakeholders have no means to judge the confidence that should be placed on these results.

- More consideration should be given to break-even analysis for assessments conducted for specific plants (especially if detailed case specific economic analyses cannot be developed). In addition, in some cases consideration should be given to the regional economic costs and benefits that could result from changes in cooling technology.

Based on the fact that several studies have been completed, it is reasonable to ask "*what is the economic value of the environmental impacts of once-through cooling in California?*" Several possible approaches to estimate such a value are available.[i] First, it might be feasible to review all of the studies done to-date at facilities throughout the U.S., in order to generate a unit value estimate (i.e., "dollar impact per million gallon per day intake"). This unit value could then be transferred to the population of California facilities to develop an overall measure of economic impacts. However, this approach is unlikely to yield valid impact measures, since there are too few existing studies to generate a robust value estimate. That is, given between-facility and between-location variations in baseline conditions and impacts, combining results from the small sample of studies that are available would be unlikely to yield a benefit estimate that can be transferred to other sites.

An alternative approach would be to apply the models developed by USEPA for the Section 316(b) rule, as discussed below, to value the environmental impacts associated with California facilities. However, in its final rule USEPA presented quantitative economic impact measures only for expected changes in recreational and commercial fish harvests. Thus, if we were to follow

USEPA's lead and only consider those two categories of economic impact, the results would likely substantially understate the overall economic impacts of once-through cooling. While it might be feasible to apply the models developed by USEPA for other benefit categories (e.g., non-use), significant concerns with these approaches have been raised.

Finally, an analysis of the total cost of providing environmental enhancement projects that off-set the impacts of once-through cooling (e.g., installation of reefs, construction of coastal wetlands) could be developed. However, as discussed below, such a cost estimate would not reflect the public's willingness to pay to avoid the environmental impacts of once-through cooling, but simply the cost of completing these projects.

Two specific research efforts could be undertaken to better incorporate economics into assessments of the environmental impact of once-through cooling and to better understand the total economic cost associated with such impacts. First, a carefully developed survey of the public intended to ascertain the public's willingness to pay to avoid the environmental impacts of once-through cooling should be developed. Such a "stated preference" survey is the only available means to assess the non-use values the public holds for these impacts. Note that such surveys do not represent an alternative to development of an accurate and detailed understanding of the biological impacts of once-through cooling. Such understanding is required to allow for development of a valid survey instrument. Second, efforts should be undertaken to establish more detailed standards for the conduct of equivalency based approaches in the context of establishing the scale of actions to off-set the impacts of once-through cooling. This would include detailed guidance that establishes the minimum data requirements for such assessments.

Below, we first provide a tabular summary of recent assessments that have been conducted at plants in California to provide context for the economics discussion which follows. We start that discussion with an overview of natural resource valuation, with a focus on the concept of "services." This section includes examples of the types of environmental services valued by people that may be impacted by the application of once-through cooling technology. It also includes an introduction to economic issues encountered in applying equivalency-based approaches, such as "habitat production foregone" to assess the environmental costs of once-through cooling. We then review commonly used valuation techniques that could be applied to assess the impacts of once-through cooling.[ii] Finally, we consider in more detail several recent analyses that have attempted to place economic values on the environmental impacts of once-through cooling in California.

Summary of Recent Studies

The table below summarizes some recent assessments of the economic value (or cost of off-setting) of environmental impacts of once-through cooling in California. These studies include assessments conducted for specific plants, as well as the regional analysis developed by EPA to assess the economic benefits of additional requirements under Section 316(b).

Note that the results obtained by these studies are not comparable, since (1) the economic valuation and cost methods used varies across the studies; (2) the categories of lost environmental services varies; (3) the size and characteristics of the facilities (including existing technology to control impingement and entrainment impacts) as well as the magnitude of the assumed change in plant operations differ; and (4) the attributes of the environment in which these plants are located differ.

Table 1. Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California				
Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
California Studies Completed				
Diablo Canyon Power Plant[1]	Estimate of the natural resource benefits associated with implementation of a closed cycle cooling system at the Diablo Canyon Power Plant (DCPP).	• Market benefits (commercial fishing) • Non-market benefits (recreational fishing) • Indirect use benefits (indirect impacts on commercial and recreational fishing) • Non-use benefits	Net Present Value (2001): $15,786 to $1,905,757 ($1,755 to $110,647 per year)	**A REVIEW COMMISSIONED BY THE CALIFORNIA CENTRAL COAST REGIONAL WATER QUALITY CONTROL BOARD CONCLUDED THAT, WHILE ASA APPROPRIATELY APPLIED AN EXISTING EPA APPROACH, THE REPORT MAY SIGNIFICANTLY UNDERESTIMATE TRUE ENTRAINMENT LOSSES (STRATUS 2003).** Dr. Pete Raimondi, an independent scientist representing the California Regional Water Quality Control Board, indicated that larval losses could be valued around $10 million. This estimate appears to be based on replacement costs using an equivalency based approach.

Table 1. Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California				
Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
	The Technical Working Group considered mitigation alternatives for addressing cooling water impacts at DCPP, including the construction of artificial reefs and establishment of a Marine Protected Area.	Artificial Reef • Estimated 296-593 acres of rock reef needed to replace larvae lost to entrainment • Artificial reef construction costs of $50,000 per acre Marine Protected Areas • Estimated costs include planning and design (initial habitat surveys, a socio-economic study, etc.), local projects (relief for fisherman, permit buyouts, etc.), process management (coordination, agency outreach, drafting reports etc.), and patrolling/management of the reserves for a limited time after they are established.	Artificial Reef Mitigation Option: $15 to 30 million Marine Protected Areas Mitigation Option: $6 to $8 million	This summary relies on a January 20, 2005 draft recommendation report.

Table 1. Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California				
Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
Morro Bay Power Plant[2]	Estimate the economic impact of once-through cooling, as measured by the cost of off-sets.	• Considers the cost of implementing representative (or equivalent) projects to off-set impacts associated with once-through cooling at $9.7 million, plus an amount to provide an additional margin of safety for program performance at $2.8 million.	Final HEP package: $12.5 million for preservation and enhancement of Morro Bay habitat	**CEC STAFF TESTIMONY SUGGESTED THAT PROPER FUNDING FOR A HEP WOULD BE $37.4 MILLION. HOWEVER, THE CEC'S FINAL DECISION DID NOT FIND THESE COST FIGURES WELL-SUPPORTED.** The Regional Board staff explored several approaches to estimate restoration costs. Estimates include: (1) $12 to $23 million based on converting larval loss to equivalent acres; and (2) $12 to $16 million using the same methodology as 1 but based on USEPA values for restoration projects.
	Duke Energy conducted a Habitat Equivalency Analysis in order to demonstrate that the proposed HEP funding level of $12.5 million provided adequate compensation.	Habitat Equivalency Analysis: • Wetted surface areas of Morro Bay is approximately 2,300 acres • Equivalent acreage: 17 percent - 33 percent of 2,300 acres = 391 – 759 acres • Assuming $30,000 per acre on average to acquire larger parcels and/or restoration of habitat.	$11.7 to $22.8 million	
Moss Landing[3]	Duke Energy North America proposed the construction of Moss Landing Power Plant (MLPPP) on the site of the existing Moss Landing generating facility. This	Habitat Restoration Cost: • Average loss: 13 percent • 13 percent of 3,000 surface acres in Elkhorn Slough = 390 wetland replacement	Final mitigation package: $7 million to enhance biological productivity in the Elkhorn Slough	

Table 1. Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California				
Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
	analysis estimates the cost of a mitigation package to compensate for expected biological losses associated with this facility.	acres • Wetland restoration cost range from $12,000 to $25,000 per acre • Total restoration costs range from $4.68 million to $9.75 million with an average of $7.215 million.		
San Onofre[4]	In connection with issuing a coastal development permit to Southern California Edison for the operation of San Onofre Nuclear Generating Station (SONGS) Units 2 and 3, the CCC required a study of the operation of the plant on the marine environment offshore from San Onofre and mitigation of estimated adverse impacts.	Habitat Restoration Cost: • Based on construction of 150 acres of kelp forests.	Estimated project cost: $51.42 million	As a result of these studies, the CCC required SCE and its partners to create or substantially restore at least 150 acres of southern California wetlands.
EPA 316(b) Final Rule[5]				

Table 1. Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California				
Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments
National Perspective	The new rule will require all large existing power plants to meet performance standards to reduce the number of organisms killed by 80 to 95 percent. Depending on location, the amount of water withdrawn, and energy generation, certain facilities will also have to meet performance standards to reduce the number of aquatic organisms drawn into the cooling system by 60 to 90 percent.	• Market benefits (commercial fishing) • Non-market benefits (recreational fishing) • Indirect use benefits (forage species that support commercial and recreational fisheries)	Affected Community: 550 facilities Estimated Benefits: $80 million annually.	
California Perspective	Average expected reductions of: • 30.9 percent for impingement • 21.0 percent for entrainment		Affected Community: 20 facilities Estimated Benefits: $3 million annually for the 20 facilities considered in the analysis. Total impacts at these facilities of $9 million.	

Table 1. Summary of Economic Analyses of the Environmental Impacts of Impingement and Entrainment in California				
Plant	Background	Methodology or Benefits Measured	Value and/or Cost Estimate	Comments

Sources:

[1] ASA Analysis and Communications, Inc. and Ivar Strand. 2003. Estimation of Potential Economic Benefits of Cooling Tower Installation at the Diablo Canyon Power Plant. Prepared for Pacific Gas & Electric Company. April 2003; Strange, L., B. Raucher. D. Cacela, D. Mills, and T. Ottem. 2003. Review of PGE's Benefits Analysis for the Diablo Canyon Power Plant. Prepared for Michael Thomas, Central California Coast Regional Water Quality Control Board. Stratus Consulting, Inc. January 22, 2003; Raimondi, P., G. Cailliet, and M. Foster. 2005. DRAFT DCPP Mitigation Recommendation. Diablo Canyon Power Plant Independent Scientist's Recommendations to the Regional Board Regarding Mitigation for Cooling Water Impacts, January 20, 2005.

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[4] [Mike Foster – Do you have a citation for this number? We found it in the first document you provided us, dated March 16, 2005 – "Environmental Losses and Mitigation Costs for Impacts of Once-Through Cooling in California."]

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Economics and Natural Resource Services

Environmental Services

As described by A. Myrick Freeman, natural resources and environmental quality are valuable assets in that they provide a flow of services to people. Changes in the magnitude or quality of these services can result from public policies and the actions of individuals and firms. These changes in turn generate benefits and costs (Freeman 2003).

Broadly speaking, these services can be categorized into market and non-market services, indirect services, and non-use services (see Exhibit E-1). Services provided by the environment can be classified as market or non-market, based on whether changes in their quality or quantity can be observed directly in economic markets. For example, changes in the total value of commercial fish landings can be measured using market data, while the economic value of changes in recreational use of a fishery must be revealed indirectly (e.g., by studying the behavioral patterns of recreationalists). Non-market services can be further divided into consumptive (e.g., recreational fishing) and non-consumptive (e.g., whale watching services). Indirect services are distinct from these categories of direct use services in that they do not directly provide a good or service to the public. For example, healthy populations of forage fish species may not create direct economic value, but do potentially enhance populations of commercially and recreationally valued species. Finally, non-use values may be associated with natural systems, reflecting the value the public may hold for these systems independent of any planned use.

Exhibit E-1

Taxonomy of Ecological Benefits[iii]
(example services)

A wide-range of human use and ecological services can be impacted by the use of ocean water for cooling by electric generating facilities. The specific types of services impacted by these facilities will vary depending on the location (e.g., near estuary, open ocean, kelp beds, rocky shoreline) and characteristics of the facility (e.g., volume of water used, location of intake and discharge structures). Thus, the first step in any assessment of the effects of once-through cooling should be to inventory potential impacts to environmental services specific to the locations involved. Some past analyses have omitted this step, instead simply focusing on service categories that were easily monetized. As a result, estimates of the total economic impact associated with once-through cooling are not available. Other studies have "transferred" economic impact results from one site or region to another without consideration of the differences in the underlying services provided (ASA 2003).

Baseline

In addition to inventorying potentially impacted services, efforts to place economic values on environmental impacts should incorporate the concept of "baseline." Baseline defines the "but for" condition of a natural resource or economic values held by the public. That is, impacts associated with once-through cooling do not exist in absolute terms, but relative to conditions that would exist in the absence of these impacts. For example, a highly industrialized area may exhibit diminished water quality even in the absence of thermal plume effects. Consideration of baseline conditions should also incorporate economic factors. For example, population growth in a region may be expected to lead to increased recreational fishing activity, and thus increased demand for (and thus the public's value for) recreationally sought-after species. Failure to sufficiently incorporate baseline conditions can lead an analysis to substantially under- or over-state economic impacts.

Willingness to Pay as the Measure of Economic Value

Economists generally define the economic value of a change in environmental services from baseline as the maximum amount of money that the public is willing to give up to make a desirable change or to avoid an adverse change (Hicks 1939; Kaldor 1939). The resulting dollar value is not in and of itself a measure of the "value" or "importance" of the change, but a measure of the quantity of other goods and services that individuals are willing to give up to have the change occur.iv This amount is referred to as the public's "willingness to pay." It is important to note that economists generally consider the public's willingness to pay for marginal changes in the environment. That is, available economic methods do not define the economic value held by the public for natural systems in the abstract (e.g., "what is the value of plankton"). Instead, these methods are used to value specific changes in environmental conditions (e.g., what is the value of a 50 percent reduction in forage fish abundance in a specific geographic area).[v] Importantly, the public's willingness to pay is not typically equal to the cost of off-setting measures to restore environmental services lost as a result of once-through cooling (i.e., cost of environmental restoration is not typically a measure of the value of such restoration).

Discounting and The Role of Time in Economic Analysis

The economic cost of modifications to cooling technology at a given facility will typically occur in the near-term, while the economic benefits of these modifications may not occur for many years into the future. In addition, the pattern of services provided over time under baseline and regulated condition may differ, making it necessary to report associated value estimates consistently. Economist's use "discounting" to assign relative weights to the value of services provided at different times. Given that the public generally places a higher value on services today versus services in the future, economists traditionally assign lower weights to the value of services provided in the future. While future benefits are typically discounted at three to 7 percent, some researchers have argued for lower rates for very long-term assessments.[vi] In any case, good practice in economics requires consistent and transparent treatment of discounting.[vii]

Uncertainty

Assessments of the economic value of environmental impacts of once-through cooling should incorporate sufficient consideration of uncertainty.[viii] No matter which valuation tool or tools are selected for a given analysis, the degree to which these tools yield accurate measures of economic impact will depend on the level of precision in the results of the underlying bio-physical models. Stakeholders should be presented with analyses that clearly communicate uncertainty introduced to the economic results by the underlying scientific models. In addition, sources of potential bias and uncertainty in the economic models should be clearly presented, and where possible, incorporated into the results. Tools commonly used to quantitatively describe uncertainty include the presentation of alternative scenarios, sensitivity analyses, and ranges. Clear communication of the underlying uncertainty in economic impact measures are especially important given that compliance cost estimates will generally be known with a much higher degree of certainty than will the likely benefits of changes in cooling technology. Many past assessments of the economic impacts of once-through cooling have failed to sufficiently report and discuss uncertainty.

Break-even Analysis

Of course, in some cases it may not be feasible to assign economic values to some of the environmental impacts associated with once-through cooling. As discussed in OMB's guidance on cost-benefit analysis:

> "It will not always be possible to express in monetary units all of the important benefits and costs….In such cases, you should exercise professional judgement in determining how important the non-quantified benefits or costs may be in the context of the overall analysis. If the non-quantified benefits or costs are likely to be important, you should carry out a "threshold" analysis to evaluate their significance. Threshold or "break-even" analysis answers the question, 'How small could the value of the non-quantified benefits be (or how large would the value of the non-quantified costs need to be) before the rule would yield zero net benefits?' In addition to threshold analysis you should indicate, where possible, which non-quantified effects are most important and why." (OMB 2003).

Given that it may be difficult to assign monetary values to some categories of services impacted by once-through cooling, break-even analysis may provide a reasonable alternative approach.

Regional Economic Impacts

Note that impacts on environmental quality associated with use of ocean water for once-through cooling may also result in changes in regional economic conditions. For example, changes in commercial fish landings could result in reductions in industry revenues and employment in related industries. These impacts are separate and distinct from measures of the public's willingness to pay, as discussed above. In addition, measures of these types of impacts are not easily compared to the costs associated with changes to cooling technology. However, in some cases consideration and quantification of these effects may provide additional information to decision-makers and the public regarding the economic effects of once-through cooling. (For an example analysis of such impacts see Leeworthy and Wiley 2003.)

Discussion of Valuation Methods

Economists have a variety of tools to estimate the value of environmental services. These techniques are not unique to the context of once-through cooling, but have been developed and applied to a wide-range of environmental economics problems. In all cases, there are well-established standards and protocols that guide the researcher and assure analytic rigor. In this section we provide a simple overview of the available techniques. More detailed descriptions and discussion can be found in USEPA 2000, Freeman 2003, and Champ et al. 2004.

In the simplest case, the value of environmental services may be reflected in actual markets. In this instance, demand functions (i.e., how the quantity of a good demanded responds to changes in the unit price of the good) can be used to estimate the value of marketed goods, after subtracting the cost of obtaining the goods and preparing them for market. For example, assessments of the economic impact of once-through cooling have frequently considered impacts on commercial fisheries markets associated with reduced fish abundance.

Typically, however, there are no observable markets for services provided by ecosystems, and thus economists rely on *non-market* valuation techniques. There are two primary types of approaches to non-market valuation – revealed preference methods and stated preference methods (see Champ et al. 2003 and Freeman 2003 for overviews of these methods). *Revealed preference methods* rely on observations of actual behavior to make inferences about individual's willingness to pay for improvements in environmental quality. For example, in *travel cost analyses* we observe that recreational anglers are willing to travel further to access fishing locations with higher catch rates. Thus, we can use information on travel costs – including individual's cost of time – to make inferences about angler's willingness to pay for improved fishing conditions (i.e., higher fish populations yielding higher catch rates). Similarly, in a *hedonic property value analysis* we observe that homes adjacent to higher quality waters command a price premium, and this premium can be used to obtain information about the value of water quality improvements to homeowners.

Stated preference methods involve development of carefully worded surveys that ask individuals directly about their willingness to pay for various ecosystem services (Mitchell and Carson 1989 and Carson et al. 1997). While stated preference surveys can be used to value a wide-range of environmental services, this family of tools is the only approach available to measure non-use values. For example, individuals may be willing to pay to preserve healthy populations of a non-commercial fish species. Since these values are not revealed in markets or in observed behavior they need to be elicited directly.

Application of stated preference techniques, especially in the context of non-use values, has been controversial, and remains an active area of research.[ix] An important challenge in using stated preference methods to value changes in natural resources or environmental quality is accurately communicating to survey respondents the nature of the service and the change in that service being valued. Designing defensible stated preference valuation surveys requires intense collaboration between natural scientists, economists, and survey researchers. Respondents ability to fully comprehend the ecological consequences of a particular action will often be limited by cognitive ability, constraints on the amount and type of information that can be presented in the survey, and the degree to which scientists themselves understand the potential consequences of the policy.

The most promising potential application of stated preference techniques in the context of valuing the impacts of once-through cooling on the environment may be in ascertaining the validity of values obtained through the replacement cost approach (see discussion of equivalency techniques below). That is, a carefully developed survey could be used to assess the total willingness to pay the public holds for improvements in the marine environment associated with additional requirements on the use of ocean water as cooling water. This willingness to pay could in turn be compared to the cost of achieving these improvements through environmental mitigation. In addition, the particular context in which once-through cooling exists provides the opportunity to ask people to trade off higher electricity bills (or, potentially, increased chance of power outages) for improvements in environmental conditions.

The market and non-market methods described above have a long pedigree in valuing environmental services in a variety of contexts. Literally thousands of studies have been conducted to guide design and implementation of environmental policy and support assessment of damages to natural resources. As a result, a secondary valuation approach referred to as *benefits transfer* has been developed. Given the high cost and long time periods that can be involved in primary valuation, benefits transfer seeks to apply existing valuation estimates to new environmental valuation problems. Various standards for the application of benefits transfer have been describe.[x]

The relative ease with which benefits transfers can be conducted introduces the potential for misuse, especially in the context of non-use values. While there is little argument that non-use values exist, especially for unique resources, the question remains as to whether there are sufficient high quality studies in the literature that value marginal changes in environmental quality of the type and magnitude provided by reductions in once-through cooling impacts. USEPA's recent attempts to develop a non-use value meta analysis for the Section 316(b) program have been met with significant criticism by an expert peer review panel. This panel found insufficient proof of similarity between the change in environmental conditions resulting from impingement and entrainment and the environmental changes valued in the literature. This panel also questioned the analytic approach used in the benefits transfer.[xi] In short, the fact that there are a large number of non-use valuation studies in the literature does not guarantee a defensible benefits transfer. Defensibility can only be established through careful adherence to existing protocols. Benefits transfer remains the most commonly applied valuation technique, and will likely remain important for valuation of once-through cooling impacts in the future.

Equivalency-Based Methods

Analyses of the economic impact of once-through cooling increasingly rely on environmental equivalency based approaches.[xii] Equivalency based approaches involve the scaling and costing out of "compensatory restoration" projects (e.g., wetland development or enhancement, artificial reef construction). These projects are intended to off-set the ecological and human-use impacts associated with once-through cooling, and thus "make the public whole" for these impacts. Estimates of environmental impacts are typically described as "debits" and the benefits of compensatory restoration projects as "credits." Discussion of two approaches for compensatory restoration scaling specific to the issue of offsetting the environmental impacts of cooling water intakes is contained in Stratus (2004).

Past applications of equivalency-based methods have implicitly or explicitly assumed that the ecological and human use impacts associated with once-through cooling can be "valued" based on the cost of such projects (i.e., that these costs are a reasonable measure of economic impact). However, while equivalency based approaches may yield estimates of the total cost of off-setting the impacts of once-through cooling, these techniques do not generate reliable measures of the public's willingness to pay for environmental or natural resource improvement. Instead, these approaches simply provide estimate of the cost of offsetting impacts associated with once-through cooling with environmental enhancement projects. These costs are referred to as "replacement costs."

As described by Shabman and Batie (1978), replacement costs represent a valid measure of economic value only if three conditions are met: (1) the replacement must provide services of equivalent quality and quantity, (2) the replacement must be the least costly alternative, and (3) individuals, in aggregate, must be willing to incur these costs if the natural resource services were not available. The first of these criteria is typically a part of the selection of restoration alternatives, and thus can usually be established. The second criterion is not typically dealt with explicitly in assessments of replacement costs for once-through cooling impacts (i.e., through a systematic analysis of possible alternatives). The final criterion is the most difficult to establish without primary economics research. In the absence of such research, analyses of restoration options for once-through cooling impacts have typically referenced past examples of public expenditures for similar projects as proof that the selected alternative meets this standard (USEPA 2000).

Even when these conditions are met, replacement cost may reflect an under-statement of true willingness to pay (since the public may have been willing to pay more). In addition, even if these conditions hold in one context there is no guarantee that they will hold in a new context. Thus, transferring these cost estimates from one region or facility to another may not yield a valid economic benefit measure.[xiii] Finally, while a number of papers have been published on habitat equivalency and related techniques, little formal guidance exists for their application (Unsworth and Bishop 1994; NOAA 1997; Mazzotta et al. 1994; Dunford et al. 2004; Fonesca et al. 2000; Penn and Tomasi 2002).

Despite these limitations, the costs of restoration (or mitigation) of the impacts of once-through cooling may provide useful information to stakeholders. For example, well-established public policies may reveal a general societal willingness to pay for specific natural resource enhancements (e.g., extensive programs requiring wetland mitigation, often at substantial cost). In these instances, past willingness to incur costs of replacement of natural resources may provide a general indication that that the cost of projects required to off-set once-through cooling impacts are not "grossly disproportionate" to the value the public places on them. More importantly, if effective in off-setting the impacts of once-through cooling, these projects may represent a cost-effective approach to impact mitigation. As noted by Robert Stavins, the cost of these projects represent less a measure of the economic impact associated with once-through cooling, and more an estimate of the cost of an alternative approach to environmental compliance.

Example Application of Economic Analysis

In this section we review several economic analyses of environmental impacts resulting from once-through cooling technology, as well as an application of an equivalency based model to establish the cost of off-setting the environmental impacts of once-through cooling. The purpose of this section is not to provide a comprehensive review of existing assessments, but a means to demonstrate the concepts and issues raised in the previous sections. Consistent with that goal, we only describe underlying biological models used to the extent that they are required to assess the economic approaches followed.[xiv]

The first analysis considered below was developed to support the USEPA's Section 316(b) Phase II Final Rule. This is not an economic assessment of the impacts of cooling water use at a particular location, but instead a general analysis of the economic benefits that could result from additional requirements on facilities that have a design cooling water intake of 50 million gallons per day or more. The other two analyses described are all for specific generating facilities.

EPA's Analysis of the Economic Benefits of the
Final Section 316(b) Phase II Existing Facilities Rule

The purpose of this EPA report was to provide an analysis of the economic benefits that could result from additional requirements to reduce impingement and entrainment at facilities that have a design cooling water intake of 50 million gallons per day or more. It is important to note that this analysis was intended to support regulatory development at the national level, not a plant-by-plant assessment of the impacts of once-through cooling. However, the analyses performed to support this rulemaking do provide benefit estimates for the 20 plants in California that would be impacted by this rulemaking.

While USEPA considered a broad range of benefit categories, their final analysis focused on assigning monetary values to three categories of benefit, each based on a different economic methodology. Specifically,

- Estimated increases in commercial catch were valued based on a market price methodology. The analysis considered the gain in commercial harvest that could be associated with reductions in impingement and entrainment. This additional harvest was then valued based on market data to yield estimates of gross revenues. These gross revenues estimates were adjusted to reflect the fact that only a portion of gross revenue represents social willingness to pay.

- Estimated changes in recreational harvests were valued based on a revealed preference model of recreational angler behavior (a random utility model).[xv]

- USEPA recognized that indirect impacts (i.e. food web impacts) on commercial and recreational use values can result from impingement and entrainment of forage species. USEPA estimated changes in commercial and recreational harvests of several species of fish, and valued these changes using the same models as described above.

- USEPA considered several methods for estimating the non-use benefits resulting from reduced environmental impacts of impingement and entrainment (benefits transfer using a meta analysis, societal revealed preference (restoration costs), and equivalency based approaches), but decided to describe these impacts qualitatively in the final rule.[xvi]

- USEPA considered a wide-range of other values (e.g., endangered species protection) that might be enhanced by reductions in impingement and entrainment, generally describing these impacts qualitatively.

EPA's assessment assumed a reduction in the biological impacts of approximately 31 percent for impingement and 21 percent for entrainment for plants in California under this rule. Based on this change in impingement and entrainment, this analysis found annual benefits of $0.5 million for commercial fishing and $2.5 million for recreational fishing. The analysis also estimates that the total value of all lost recreational fishing opportunities due to impingement and entrainment to currently be approximately $7 million per year, and commercial fishing losses to be about $2 million per year (present value). This analysis, by focusing on commercial and recreationally valued species, does not address the values of reducing losses to other species (of the 248 species reported as impinged or entrained, 20 are harvested). With 20 plants in California, the commercial and recreational losses associated with any one plant will be relatively modest when compared to the cost of alternative cooling technologies.

Overall, this analysis provides the most exhaustive assessment of the value of environmental impacts associated with once-thorough cooling. However, several factors likely lead this analysis to understate the benefits associated with reductions in the impacts of once-through cooling. First, it considers only a subset of the species that are impacted by these facilities. Second, in presenting the final costs and benefits of the rule, USEPA chose only to present a limited subset of these values – the direct and indirect impacts associated with commercial and recreational fishing. While USEPA considered several methods to estimate non-use values (as well as other categories of benefit), in the end they decided that uncertainties in the methods and results were too significant to allow for presentation of national benefit measures. As a result, the final results understate total benefits of reductions in the environmental impacts of once-through cooling, probably to a significant degree.

Estimation of Potential Economic Benefits of Cooling Tower Installation at the Diablo Canyon Power Plant[xvii]

The Pacific Gas and Electric Company commissioned a study of the economic benefits of reductions in entrainment losses that could arise from installation of cooling towers at the Diablo Canyon Power Plant. These benefit estimates were intended for comparison to the estimated costs for cooling tower installation. The benefit categories considered and the methods used were partly drawn from recent work by USEPA to assess the benefits of actions to reduce impingement and entrainment impacts.

The biological model used in this report considers the magnitude of reductions in entrainment that would result from cooling tower installation. The assessment then considers four categories of economic benefit: market benefits (for commercial fishing), non-market benefits (for recreational fishing), indirect use benefits, and non-use benefits.

The analysis estimates the change in commercial catch that would be expected to result from closed-cycle cooling, as well as the economic value of that catch. The analysis does not assume that all lost fish would be caught, but assumes a range of exploitation of 10 to 50 percent. Since a portion of these fish would be harvested by recreationalists, the analysis apportions fish to the commercial and recreational sectors on a species by species basis. Lost harvest to the commercial sector was then multiplied by market prices in the commercial fishery to estimate the change in revenue experienced by commercial fishermen. In keeping with economic conventions, the analysis assumed that a large portion of this revenue stream represented the cost of harvest, with the remainder reflecting the public's willingness to pay for the enhanced commercial harvest (that is, the cost of harvest is not included since it is not incurred in the absence of fish). For expected changes in recreational harvests, the analysis relied on a transfer of values for caught fish from an existing analysis in a similar geographic region, ranging from $5 to $25 per fish for popular recreationally targeted species. For less popular (non-targeted) species, a commercial value was used.

This analysis recognized that enhanced populations of forage species provide an indirect benefit to the public, and thus applied a model to estimate the contribution of forage fish species to the abundance of targeted species. Specifically, the analysis assumes that impacted forage species would be consumed by California halibut, a commercially and recreationally popular species. The study authors explicitly consider and reject application of a replacement cost estimate for these indirect use benefits, since "the cost of production is a function of the difficulty of rearing and has nothing to do with the economic value of these species."

Finally, the authors assume that non-use values are equal to 50 percent of recreational use values. This assumption is drawn from a draft analysis by the USEPA of the economic benefits of the Section 316(b) rule. A number of studies have considered both the non-use and use values associated with changes in water quality, and thus provide a means to calculate a ratio of use to non-use values. However, these ratios vary substantially between studies and resources, and thus there is little empirical (or theoretical) basis for the assumption that non-use values will be a function of use values. In short, few economists would support application of this "rule of thumb."

The analysis concludes that implementation of a closed cycle cooling system at Diablo Canyon would result in a net present value benefit of $16,000 to $1.9 million. Two subsequent reviews of this report were developed by consultants to the Regional Board. The first (Strange 2003), concluded that the approach used and assumptions made would likely lead to an underestimate of benefits, because most of the entrained taxa were not incorporated in the analysis. In a separate review, Dr. Raimondi concluded that larval losses could be valued in the $10 million range, depending on the assumptions made. This estimate appears to be based on an equivalency approach (e.g., the cost of undertaking restoration to offset the biological impacts of impingement and entrainment).

Overall, this analysis considers a relatively wide-range of economic services and conducts several sensitivity tests of important assumptions. It also provides a transparent present value analysis, discounting the expected flow of future benefits to allow comparison of the expected costs of alternative cooling technologies to the benefits of such technologies.[xviii]

Duke Energy Morro Bay LLC, Morro Bay Power Plant Modernization Project Habitat Enhancement Program (HEP), 2002[xix]

Duke Energy conducted a habitat equivalency analysis of impacts resulting from the use of ocean water as cooling water for the Morro Bay Power Plant. To estimate the ecological impact associated with cooling water use, Duke considered the total biomass of fish and crab larvae entrained as a measure of the ecological service loss. They note that not all organisms entrained were included in the biomass estimate, but it was assumed that those measured are good indicators of all entrained species. The analysis also notes that the fish and crabs measured are important to recreational and commercial activities in the bay (and thus, presumably, are the species to focus on in the analysis). The analysis assumes that 100 percent of all entrained organisms suffer mortality, and that all of these organisms would have remained in Morro Bay. The future flow of these services was discounted using a rate of three-percent.

The analysis then considers possible habitat restoration projects that would provide larval fish and shellfish biomass, including coastal salt marsh and eelgrass beds. Specifically, the analysis uses estimates of the primary productivity of these two habitat types to determine the number of acres of habitat required to offset losses due to entrainment. The analysis concludes that 57.2 acres of eelgrass or coastal salt marsh creation would be required to offset entrainment losses.

While the Duke report discusses various factors that may lead the analysis to overstate impacts, no attempt is made to quantitatively track these uncertainties formally. Given uncertainties on both the “debit” and “credit” side of the analysis, a more formal assessment would provide greater confidence that the overall results of the analysis are in fact conservative.

The report also raises an important point: the habitats provided as an off-set for once-through cooling impacts likely provide other benefits. However, no attempt is made to assess the scale of this credit.

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[i] In order to place a value on the environmental impacts of once-through cooling in California, we would also need to characterize the bio-physical impacts generated by these facilities. This discussion focuses solely on the availability of economic methods.

[ii] Our discussion of economic valuation methods is not intended to be exhaustive, nor is it intended to offer detailed guidance on the application of these techniques. Numerous published authorities are available that provide such guidance (see, e.g., Freeman 2003; USEPA 2000; Champ et al. 2004).

[iii] Derived from USEPA (2000) and other sources.

[iv] This distinction may have particular relevance in this context, where environmental requirements valued by the public may lead directly to higher utility bills for that same public.

[v] Recently, several researchers have attempted to assign a total value to ecosystems (e.g., Costanza et al. 1997). As noted by the USEPA, "the results of these studies should not be incorporated into benefits assessments. The methods adopted in these studies are not well grounded in economic theory nor are they typically applicable to policy analysis." (USEPA, 2000, page 98). For a critique of these approaches, see Bockstael et al. 2000.

[vi] See Weitzman 1998; Weitzman 2001.

[vii] See USEPA 2000; U.S. OMB 2003; NOAA 1999; USDOI's Natural Resource Damage Assessments Regulations can be found at 43 CR Section 11.84(d).

[viii] Guidance on consideration of uncertainty in environmental benefits assessment can be found in USEPA 2000; U.S. OMB 2003; USDOI's Natural Resource Damage Assessments Regulations can be found at 43 CR Section 11.84(d).

[ix] See USEPA 2000.

[x] See USEPA 2000; Kirchhoff et al. 1997; VanderBerg et al. 2001; North Carolina State University Center for Environmental and Resource Economics Policy 2001; Unsworth and Peterson 1995; Desvouges et al. 1998; AERE 1992.

[xi] Unsworth, R. 2005. Personal communication with members of the EPA's Section 316(b) Phase II Final Rule peer review panel.

[xii] These include techniques such as habitat equivalency analysis (HEA), resource equivalency analysis (REA), habitat production foregone (HPF), net environmental benefit analysis (NEBA), and others. All of these techniques are based on the construct of replacing lost or diminished natural resources with in-kind or out-of-kind replacement resources that provide the same or similar services. In the case of HEA, economic equivalency is typically assumed based on the similarity of the resources lost and those provided, but no specific economic analysis is constructed. The application of these techniques arose from natural resource damage assessment (e.g., Unsworth and Bishop 1994 and NOAA 1997), and equivalency based assessments are currently being applied in a variety of contexts.

[xiii] In some cases, well-established public policies may reveal societal willingness to pay for specific natural resource enhancements (e.g., extensive programs requiring wetland mitigation, often at substantial cost). In these instances the cost of replacement of natural resources may provide an indication that that the cost of projects required to off-set impacts are not "grossly disproportionate" to the value the public places on them.

[xiv] In addition, no attempt has been made to replicate the results presented in these existing analyses.

[xv] For one region of the country USEPA used a benefits transfer approach to recreational fishery valuation.

[xvi] As noted previously, a recent peer review panel considered the non-use portion of USEPA's analysis and is expected to raise several fundamental concerns, including the linkage of the studies considered from the literature to the changes expected to result from this rulemaking, as well as the overall quality of the analysis.

[xvii] ASA, 2003.

[xviii] A critique of this report was developed by the California Central Coast Regional Water Quality Control Board (see Strange et al. 2002).

[xix] This report was developed as a component of Duke Energy's efforts to modernize the Morro Bay Power Plant. Duke Energy's stated intention in presenting a habitat equivalency analysis was to "demonstrate the conservative nature of the Regional Board's approach and validate

scientifically the magnitude of the safety margin that is incorporated into the HEP (habitat enhancement program).” (page 47)